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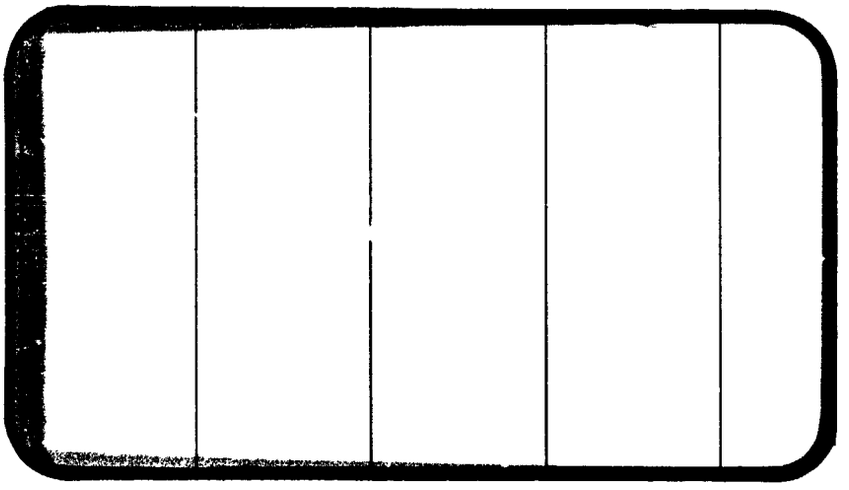

(NASA-CR-134425) A HYPERSONIC FORCE AND
PCMENT TEST OF A 0.006 SCALE MODEL (466)
OF THE 330.2 INCH DIAMETER EXTERNAL TANK
IN THE AMES RESEARCH CENTER (Chrysler
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SPACE SHUTTLE

AEROTHERMODYNAMIC DATA REPORT

JOHNSON SPACE CENTER

HOUSTON, TEXAS

DATA MANagement services

SPACE DIVISION CHRYSLER CORPORATION

November, 1974

S-DR-2181
NASA CR-134,425

A HYPERSONIC FORCE AND MENT TEST OF A 0.006 SCALE MODEL (466) OF THE 330.2 INCH DI ETER EXTE AL TANK IN THE AMES RESEARCH CENTER 3.5 FOOT HYPERSONIC WIND TUNNEL (TA9F)

By

P. E. Ramsey, MSFC
T. C. Davis, NSI

Prepared under NASA Contract Number NAS9-13247

by

Data Management Services
Chrysler Corporation Space Division
New Orleans, La. 70189

for

Engineering Analysis Division

Johnson Space Center
National Aeronautics and Space Administration
Houston, Texas

WIND TUNNEL TEST SPECIFICS:

Test Number:	ARC 3.5 HWT 196
NASA Series Number:	TA9F
Test Dates:	30 May through 12 June 74
Occupancy Hours:	120
Model Number:	466

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A HYPERSONIC FORCE AND MOMENT TEST OF A 0.006 SCALE MODEL (466) OF THE 330.2 INCH DIAMETER EXTERNAL TANK IN THE AMES RESEARCH CENTER 3.5 FOOT HYPERSONIC WIND TUNNEL (TA9F)

By

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ABSTRACT

A wind tunnel force and nt test of the Space Shuttle External Tank (NASA series test number TA9F) was conducted at the Ames Research Center 3.5 Foot Hypersonic Wind Tunnel during June of 1974. The wind tunnel model was a 0.006 scale model of the 330.2 inch diameter External Tank with nose cap and lightning rod.

Data were obtained over an angle-of-attack range from 0 to 180 degrees at Mach numbers of 5.3 and 10.4. Body roll angles varied from 0 to 315 degrees for the Mach number 10.4 tests. A constant roll angle of 180 degrees was used for all Mach number 5.3 tests. The effects of protuberances and Reynolds number on the force and moment coefficients were investigated.

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PLOT SCHE LES:

A) CNM, CA, CL , CYM, CY , CBL, XCP/L VS. ALPHA

B) CAF, CAB VS. ALPHA

C) C , CA, C , CYM, CYNM, CBL, XCP/L VS. PHI

D) CAF, VS. PHI

E) DC , , DC , DCYM, DCYNM, DCBL VS. ALPHA

F) F, DC VS. ALPHA

INTRODUCTION

The Space Shuttle External Tank (ET) will be separated from the Orbiter before orbit is achieved. The ET will then reenter the a sphere at hypersonic speeds. Since the ET is not designed structurally to withstand reentry, the combined force and heat loads are expected to break it up before impact in the Indian Ocean. The size of the "footprint" fo d by falling pieces of the ET will depend on the altitude that breakup occurs. Therefore, to predict the altitude of breakup and thus the footprint, reliable estimates of aerodynamic heating rates and forces and nts must be obtained over the entire reentry trajectory. The purpose of this report is to present the results of a hypersonic force and nt test of the ET in the s Research Center 3.5' hypersonic tunnel.

The model tested was a 0.0 scale representation of the 330.2" diameter External Tank with nose cap. Photographs of the model, installed in the tunnel, are presented in Figures 3a through 3c. The configuration reference drawing is Rockwell International drawing VL78-00 62B. A reproduction of the basic ET f this drawing is shown in Figure 2a. The del included scaled protuberances.

The test was conducted primarily at a ch number of 10.4 but s data were taken at ch 5.3. For Mach 10.4, data were recorded at thirty-six ( ) angles-of-attack between 0° and 1 ° and at eight (8) roll angles t en 0° and 360°. At ch 5.3, data were obtained only at 1 ° roll angle and at angles-of-attack bet n 0° and 180°. The test covered a ran of Reynolds n bers that correspond to an altitude range t n

35,000 and 80,000 feet as defined in the trajectory of Reference 1. Since portions of the test occurred near the transition flow regime, data at Mach 10.4 and roll angle of 0° were taken at the maxi and minimum Reynolds number capability of the facility to check for variation with Reynolds number.

The test required approximately 120 hours of test time. It began y 30, 1974. The test was assigned a test number of 196 and a SA series number of TA9F.

N ENCLATURE

GENE L

SYM L	PLOT SYM L	DEFINITI	UNITS
A_b		base area; cross-sectional area of the cylindrical ET	$in.^2$
A_c		cavity area, area of the opening required for the balance and sting	$in.^2$
		Balance nt Center	
b_{ref}	B F	reference span; diameter of the cylindrical section of the el	in.
c.g.		center of gravity	
ET		External Tank	
F_A		axial force (AF), positive in the negative direction of x	lb
F_N		no l force (NF), positive in the negative direction of z	lb
F_Y		side force (SF), positive in the positive direction of y	lb
ℓ_{ref}	LREF	reference length; dia ter of the cylindrical section of the el	in.
M	CH	ch number	
MRP	P	nt Reference Point (Located in the x, y, z axes by , YMRP, and RP)	
M_x		rolling nt ( ); a t about the x-axis (a positive rolling nt tends to rotate the positive y-axis t rd the positive z-axis)	in.-lb

N NCLATURE (Continued)

SY OL	PLOT SY OL	FINITI	UNITS
M_y		pitching nt ( ); a nt about the y-axis (a positive pitching nt tends to rotate the positive z-axis toward the positive x-axis)	in.-lb
M_z		yawing nt ( ); a nt about the z-axis (a positive yawing nt tends to rotate the positive x-axis t rd the positive y-axis)	in.-lb
q_∞	Q(PSI)	f stream dvnamic pressure	psi
/L	/L	unit ynolds n r	ner ft
S_{ref}	SREF	reference area; cross-sectional area of the cylindrical ET	$in.^2$
P		pressure	psi
SRB		Solid Rocket ster	
T		t rature, °F	

MISSILE IS SYSTEM C FFICIE S

C_{A_m}	CA	axial force; $F_A/q_\infty S_{ref}$
C_{A_b}		se axial force; $(P_\infty-P_b) A_b/q_\infty S_{ref}$
$C_{A_{f_m}}$	CAF	fore axial force; $C_A - C_{A_b}$
C	CBL	rolling t; $M_x/q_\infty S_{ref} b_{ref}$
C_{m_m}	C	pitching t; $M_y/q_\infty S_{ref} \ell_{ref}$
C_{N_m}	C	i.o l force; $F_N/q_\infty S_{ref}$

N ENCLATURE (Continued)

SY OL	PLOT SY L	DEFINITI
Cn_m	CYNM	yawing . nt; M_Z/q_∞ Sref bref
Cp	CP	pressure coefficient; $(P_1-P_\infty)/q_\infty$
Cy_m	CYM	side force; F_Y/q_∞ Sref
ΔC	DCA	incremental axial force coefficient
ΔC_{A_b}	DC	incr ntal base axial force coefficient
$\Delta C_{A_{f_m}}$	AF	incr ntal fore y axial force coefficient
ΔC_{ℓ_m}	DCBL	incr ntal rolling nt coefficient
ΔC		inc ntal no l force coefficient
ΔC_{m_m}		inc ntal pitching nt coefficient
ΔC_{n_m}	DCY	incr ntal yawing nt coefficient
ΔCy_m	DCYM	incr tal side force coefficient
X_{cp}/ℓ	XCP/L	center of pressure location, where XCP is the center of pressure location in te of the deci l fraction of ET length (1846.9) aft of the ET nose (sta 328.92), XCP/L=0.5832-0.17 (C /CNM)
ϕ	PHI	angle of roll, g. (f a pilot's viewpoint in an airplane, a positive roll angle is a clockwise rotation)
TC		test condition n r, see Test Condition Section
ref		subscript, reference conditions
∞		subscript, freestre conditions
b		subscript, base
c		subscript, cavity

NOMENCLATURE (Concluded)

SYMBOL	PLOT SYMBOL	DEFINITION
t		subscript, total conditions
m		subscript, missile axis
α		angle of attack in the body axis system, degrees
β	BETA	angle of sideslip in the body axis system, degrees.
α_T	ALPHA	angle of attack in the missile axis system, degrees.

CONFIGURATIONS INVESTIGATED

The model configuration for this test was defined by Rockwell International drawing VL78-000062B. A part of this drawing is reproduced in Figure 2a.

The model is a 0.006 scale representation of the Space Shuttle External Tank. Model length including the nose cap is 11.303 inches and model diameter is 1.98 inches. The model was machined in several parts to allow maximum utilization of all model parts while testing with different sting arrangements. The model could be mounted on the sting by the nose, tail or side. This allowed coverage of angles-of-attack from 0° to 180° with minimum sting interference. The basic model parts are the nose tip, the nose plug, the nose, the center body, the base and the base plug. These parts are shown in Figure 2b. Two center bodies were constructed. The first one, to be tested in the nose or tail mounted positions, could be rotated to cover the 0° to 315° roll angle range without removal of the protuberances. The second, to be tested in the side mount position, could not be rotated. All center body protuberances had to be moved each time a new roll angle was desired. The nose and tail sections were rotated to cover all of the roll angles without removing the protuberances. Drawings of these sections are shown in Figures 2c through 2i.

Only the largest protuberances were modeled (see Fig. 2a). They included the Orbiter-ET attach structure (forward and aft), the forward and aft SRB attach structure, LO_2 feed line, LO_2 recirculation line with electrical conduit and the LH_2 pressure line with electrical conduit.

Drawings for the protuberances are shown in Figure 2h and in Figures 2j through 2q.

Because of the high temperatures encountered in this test, the balance was insulated with a sleeve especially built for the model. A drawing of the sleeve is shown in Figure 2r. The sleeve was built in 3 layers as shown. The inner layer, which was closest to the balance, was .125 inch thick stainless steel. The outer layer was also stainless steel and was .089 inch thick. The middle layer, or insulating material, was .25 inch thick and made from "G-10 Epoxy Glass" insulation material. The thermal conductivity of this material is 4×10^{-4} cal/sec/cm^2/°C/cm. The insulation was machined for a press fit between the inner and outer layers. Eight (8) epoxy glass dowel pins were used to pe nently bind all three layers together. A hole through the three layers in four places was used to attach the sleeve to the 3/4 inch diameter Task balance. The sleeve was then placed into the center body and pinned to the y in 2 places. The sleeve contained 8 holes, each equally spaced, to accept the 2 pins. These holes allowed the center body (for the 10° sting) to be rolled in 45° increments around the sleeve. There were no heat paths directly through the model to the balance. No heating problems were encountered during the test.

The model support hardware consisted of a 10° sting, a 90° sting and a sting adapter to connect the sting to the tunnel strut.

An assembly drawing of the model mounted in all three positions is shown in Figure 2s.

TEST FACILITY DESCRIPTION

The Ames 3.5 foot Hypersonic Wind Tunnel is a closed circuit blowdown tunnel capable of operating at nominal Mach numbers of 5.2, 7.4 and 10.4; at pressures to 1800 psia and temperatures to 3400°R for run times to four minutes. The major components of the facility include a gas storage system where the test gas is stored at 3000 psi, a storage heater filled with aluminum - oxide cored brick capable of heating the test gas to 3400°R, contoured nozzles with exit diameters of 42 inches for generating the desired Mach number, and a 900,000 ft^3 vacuum storage system which operates to pressures of 0.3 psia. The test section itself is an open-jet type enclosed within a chamber approximately 12 feet in diameter and 40 feet in length, arranged transversely to the flow direction. The length of the jet is approximately 10 feet.

A model support system is provided that can pitch models through an angle-of-attack range of -20 to +18 degrees, in a vertical plane, about a fixed point 1 to 5 feet from the nozzle exit plane. The model is normally out of the test stream until the tunnel test conditions are established, after which it is inserted. Insertion time is adjustable to as little as 1/2 second and models may be inserted at any strut angle. A closed circuit video system with a recorder is available for visually monitoring the experiments within the test cabin.

A data acquisition system accepts analog signals at rates up to 2500 samples per second, converts them into digital form and records on magnetic tape for later reduction by a digital computer.

The tunnel operates two 8-hour shifts per 24-hour day.

INSTRUMENTATION

The balance used in this test was a .75 inch diameter Task balance. The balance is a six component internal strain gage balance. The reference balance drawing furnished by Ames is 6656. The description number given the balance is MK XXIX 6656 B. The load range of the balance is:

Normal Force	=	200 lb
Pitching M nt	=	200 in-lb
Side Force	=	100 lb
Yawing Moment	=	100 in-lb
Axial Force	=	30 lb
Rolling Moment	=	30 in-lb

Because of the small loads at Mach 10.4 as compared to Mach 5.3, a 1/2 load balance calibration was performed. This calibration was used in the data reduction for runs at Mach 10.4. The normal full scale calibration was used in the data reduction for runs at Mach 5.3.

TEST CONDITIONS

The test program consisted of approximately 120 hours of tunnel time. The angle-of-attack range was 0° to 180° in five degree increments. Two stings were used in an effort to minimize sting interference over the angle-of-attack range. The first one, the 10° sting, could be mounted in the nose or tail of the model and was used for angle-of-attack ranges -5° to 30° and 150° to 185°. The angle-of-attack range 30° to 150° was covered using a 90° sting mounted from the side of the model.

Because the sector of the tunnel is only capable of an angle range of -20° to 18°, the sting was mounted in one of three positions on the strut. These positions are assigned a number and are shown in Figure 2t. Number 1 position was 40° above the strut centerline. Number 2 position was on the strut centerline and number 3 was 40° below the strut centerline. In each case the center of rotation was the same. The following notation was used to denote the range to be covered on a run:

NOTATION	STRUT POSITION	STING	STING POSITION	MODEL α RANGE	SECTOR α RANGE
A'	2	10°	Tail	-5° to 30°	-20° to 15°
G	1	90°	Side	30° to 60°	-20° to 15°
F	2	90°	Side	70° to 105°	-20° to 15°
E	3	90°	Side	110° to 145°	-20° to 15°
C'	2	10°	Nose	150° to 185°	-20° to 15°

All increments are 5°

This schedule is illustrated pictorially in Figure 2t.

TEST CONDITIONS (Concluded)

The angle of roll was varied from 0° to 315° in 45° increments. When 10° sting was used the entire model could be rolled about the sting. This eliminated the necessity of removing all protuberances on every run. When the 90° sting was being used, the protuberances located on the center body were removed and relocated. Both the nose and tail could be rotated and protuberances located there were not removed. Runs were made with and without protuberances (clean body).

Test conditions at Mach 5.3 were chosen to restrict the dynamic pressure to a value that would not overload the balance. Test conditions for the runs at Mach 10.4 were chosen on the following bases: An intermediate stagnation pressure and temperature that allowed fast re-cycle time of the tunnel (determined by discussion with Ames personnel); a low and high stagnation pressure and temperature that allow data to be checked on a similarity parameter basis. The resulting test conditions are shown in the following table:

CONDITION NUMBER	M_∞	P_t (psia)	q_∞ (psi)	T_t (°R)	TEST TIME (sec)	R_N/ft x 10^{-6}
1	5.3	275	7.184	1200	140	3.81
2	10.4	400	.512	2000	100	.39
3	10.4	1200	1.720	2000	160	1.16
4	10.4	1800	2.303	2000	180	1.74

DATA REDUCTION

Parameters measured and recorded during this test were:

- o Wind tunnel conditions (P_∞, P_t, T_t)
- o Six-component force and moment data
- o Sting attitude
- o Base pressure (on the runs where the angle-of-attack range was either -5° to 30° or 150° to 185°).

Tunnel conditions were used to calculate the Mach number, the dynamic pressure, and the Reynolds number; the six-component force and moment data were used to calculate static stability coefficients; the sting attitude and initial model attitude were used to calculate the model angle-of-attack, and the base pressures were used to calculate base pressure coefficients.

The following equations were used to reduce force and moment data to non-dimensional coefficients in the missile axis system.

C_{N_m} = normal force coefficient
= $F_N/q_\infty S_{ref}$

C_{m_m} = pitching moment coefficient
= $M_y/q_\infty S_{ref} \ell_{ref}$

C_{A_m} = axial force coefficient
= $F_A/q_\infty S_{ref}$

C_{Y_m} = side force coefficient
= $F_Y/q_\infty S_{ref}$

C_{n_m} = yawing moment coefficient
= $M_Z/q_\infty S_{ref} b_{ref}$

C_{ℓ_m} = rolling nt coefficient

= $M_x/q_\infty S_{ref} b_{ref}$

$C_{A_{b_m}}$ = base axial force coefficient

= $(P_\infty - P_b) A_b/q_\infty S_{ref}$

The positive directions of the forces and m nts are shown in Figure 1.

The following reference data were used to reduce the force and moment data to aerodynamic coefficients:

S_{ref} = 3.08 in.^{2}

ℓ_{ref} = 1.98 in.

b_{ref} = 1.98 in.

A_b = 3.08 in.^{2}

The m nt reference point for this external tank configuration was at a tank X station of 1406 (see Fig. 2a). This placed the MRP 1.08 inches aft of the .

The center of pressure location was calculated as follows:

XCP/L = 0.5832 - 0.17 (CL /C)

where 0.5832 = $(X_{T_{MRP}} - X_{T_{NOSE}})/L_{TANK}$

0.1788 = LREF/L_T K

$X_{T_{MRP}}$ = ET MRP station

$X_{T_{NOSE}}$ = ET nose station

L_T K = ET length

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2. Uken, D. H., "A Hypersonic Aerodynamic Analysis of the Space Shuttle External Tank During Reentry", Northrop Services, Inc., M-9230-73-240, November 1973.

3. Experimental Fluid Dynamics Branch, "Test Planning Information for the NASA- s 3.5-Foot Hypersonic Wind Tunnel", AMES Research Center.

4. Robertson, Michael K., "A Pre-Test Report for MSFC TWT 583, An Investigation to Determine the Static Stability During Re-entry of the .003-Scale MCR 0200 Baseline Space Shuttle External Tank Model in the NASA-MSFC 14 x 14-Inch Trisonic Wind Tunnel", Northrop Services, Inc., M-9230-74-261, February 1974.

5. Davis, Tommy, "A Pre-Test Report for a Hypersonic Force and M nt Test of the .006 Scale 330.2 Inch Diameter External Tank in the Ames Research Center 3.5 Ft. Hypersonic Wind Tunnel", Northrop Services, Inc., M-9230-74-283, May 1974.

TABLE I.
TEST CONDITIONS
TEST 196

MACH NUMBER	REYNOLDS NUMBER per foot	DYNAMIC PRESSURE (pounds/sq. inch)	STAGNATION TEMPERATURE (degrees Fahrenheit)
5.3	3.81×10^6	7.184	740
10.4	3.90×10^5	.512	1540
10.4	1.16×10^6	1.720	1540
10.4	1.74×10^6	2.303	1540

CE UTILIZED: MK XXIX 6656 B

C ACITY:

NF 200 lb
SF 100 lb
AF 30 lb
PM 200 in.-lb
100 in.-lb
30 in.-lb

ACCURACY:

COEFFICIENT
TOLE CE:

CO NTS:

TABLE II.

TEST: ARC 3.5 196 (TAPE)

DATA SET RUN NUMBER COLLATION SUMMARY

DATE: JUNE 1974

DATA SET IDENTIFIER	CONFIGURATION	SCHD. α	SCHD. β	CONTROL DEFLECTION MACH	CONTROL DEFLECTION RN/L	NO. OF RUNS	PHI (φ) (OR ALTERNATE INDEPENDENT VARIABLE) 0	45	90	135	180	225	270	315	TEST RUN NUMBERS
REYMA1	TANK WITH	A'	0	10.4	1.16	8	18	17	16	15	14	13	12	11	
G1	PROTUBERANCES	G				8	22	27	28	33	34	39	40	45	
F1		F				8	23	26	57	32	35	38	41	44	
E1		E				8	24	25	30	31	36	37	42	43	
C1		C'				8	3	4	5	6	7	8	9	10	
REYMA2	BASIC TANK	A'	0	10.4	1.16	1	1								
G2		G				1	21								
F2		F				1	19								
E2		E				1	20								
C2		C'				1	2								
REYMA3	TANK WITH	A'	0	5.3	3.81	1					54				
G3	PROTUBERANCES	G				1					48				
F3		F				1					49				
E3		E				1					52				
C3		C'				1					53				

1 7 13 19 25 31 37 43 49 55 61 67 75 76

CAM . . CYM . . CA . . . CLMM . CYMM . CBL . . *CAB . . MACH . XCP/L . . . . . PHI . . . ALPHA. 0.9

α OR β SCHEDULES

COEFFICENTS

$\alpha(A') = -5° \rightarrow 30°$ ($\Delta\alpha = 5°$), $\alpha(F) = 70° \rightarrow 105°$ ($\Delta\alpha = 5°$), $\alpha(C') = 150° \rightarrow 185°$ ($\Delta\alpha = 5°$)

$\alpha(G) = 30° \rightarrow 70°$ ($\Delta\alpha = 5°$), $\alpha(E) = 110° \rightarrow 150°$ ($\Delta\alpha = 5°$)

IDVAR (1) IDVAR (2) NDV

*CAB FOR DATA SETS REYMA1, C1, A2, C2, A3, C3, A4, AND A5 ONLY

TABLE II

TEST: ARC 3 5 14L (TAAF)

DATA SET RUN NUMBER COLLATION SUMMARY

DATE: JUNE 1974

DATA SET IDENTIFIER	CONFIGURATION	SCHD. α	SCHD. β	CONTROL DEFLECTION MACH	CONTROL DEFLECTION RN/L	NO. OF RUNS	PHI (Φ) (OR ALTERNATE INDEPENDENT VARIABLE) 0	45	90	135	180	225	270	315	TEST RUN NUMBERS
REYMA4	TANK WITH	A'	0	10.4	0.34	1	55								
G4	PROTUBERANCES	G	↓	↓	↓	1	46								
F4	↓	F	↓	↓	↓	1	50								
REYMA5	TANK WITH	A'	0	10.4	1.74	1	56								
G5	PROTUBERANCES	G	↓	↓	↓	1	47								
F5	↓	F	↓	↓	↓	1	51								
REYMA6	TANK WITH PROTUBERANCES	A'	0	10.4	0.39	1					59				
G6	↓	G	↓	↓	↓	1					58				
REYMA7	TANK WITH PROTUBERANCES	A'	0	10.4	1.16	1					60				

1 7 13 19 25 31 37 43 49 55 61 67 75 76

α OR β SCHEDULES — COEFFICENTS — IDVAR (1) — IDVAR (2) — NDV

TABLE III.
DEL DIMENSIO DATA

DEL CO ONENT: EXTERNAL TANK (ET)

GENERAL DESCRIPTION: EXTERNAL OXYGEN-HYDROGEN TANK (MACHINED IN SIX PARTS)

MODEL SCALE = .006

DRAWING NUMBER: V1.78-000062B

DIMENSIONS:	RE -	A EL MODEL S E
Length, IN. (NOSE @ X_T=298)	1883.8	11.303 IN.
Max. Width, IN. (DIA)	330.2	1.98 IN.
x. Depth		
Fineness Ratio	5.71	5.71
Area		
x. Cross-Sectional		3.08 IN.^{2}
Planform		
Wetted		
Base		3.08 IN.^{2}

TABLE III. (Continued)

L COMPONENT: ATTACH STRUCTURE

RAL DESCRIPTION: FORWARD ORBITER/ET - ATTACH STRUCTURE

SCALE = .006

DRAWING NUMBER: VL78-000062B

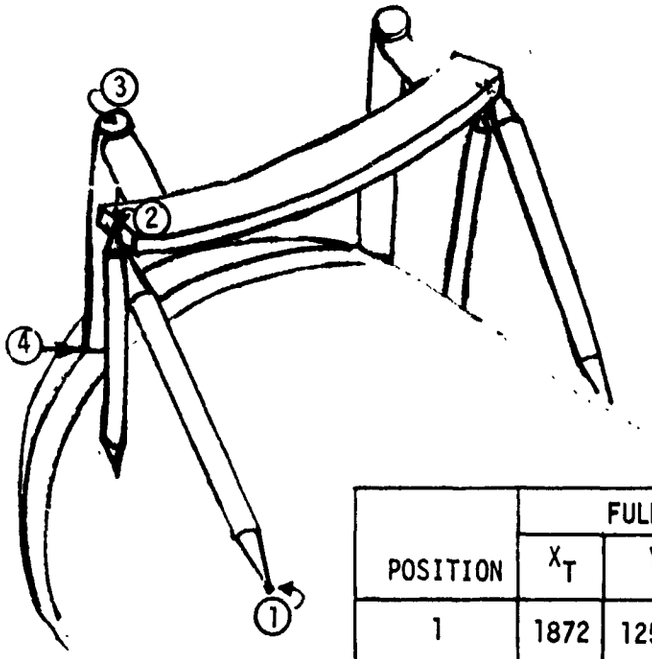
DIMENSIONS:		THEORETICAL FULL-SCALE	THEORETICAL MODEL SCALE	A AL MEASURED MODEL SCALE
L TION OF CENTER				
	X_T	1129.9	6.78	
	Y_T	0.0	0.0	
	Z_T	214.0	1.284	
AN MADE BY MEMBERS =		92°40'	92°40'	
DIAMETER OF MEMBERS =		5.67	.034	

TABLE III. (Continued)

MODEL COMPONENT: ATTACH STRUCTURE

GENERAL DESCRIPTION: REAR ORBITER ET ATTACH STRUCTURE. STRUCTURE IS MADE WITH BASE (PART NO. 80M42703).

DRAWING NUMBER: VL78-000062B and SK-RL 21974



POSITION	FULL SCALE			MODEL SCALE		
	X_T	Y_T	Z_T	X_T	Y_T	Z_T
1	1872	125.68	115.50	11.232	.754	.693
2	2058	96.50	203.56	12.348	.579	1.221
3	2088	70.0	203.56	12.528	.42	1.221
4	2088	70.0	100.00	12.528	.42	.6

*FOR DETAIL MODEL DIMENSIONS SEE FIGURE 2g.

TABLE III. (Continued)

MODEL COMPONENT: CENTER BODY AND BASE PROTUBERANCE NUMBER 1

GENERAL DESCRIPTION: LH_2 PRESSURE LINE AND ELECTRICAL CONDUIT

MODEL SCALE = .006

DRAWING NUMBER: VL78-000062B

DIMENSIONS: (INCHES)	THEORETICAL FULL-SCALE	THEORETICAL MODEL SCALE	ACTUAL MEASURED MODEL SCALE
HEIGHT	5.0	.03	
WIDTH	10.0	.06	
X_T (BEGINNING)	1040	6.24	
X_T (ENDING)	2052	12.312	
RADIAL POSITION	33°45'	-35°9'	

TABLE III. (Continued)

MODEL COMPONENT: NOSE AND NOSE PLUG PROTUBERANCE

GENERAL DESCRIPTION: LO_2 PRESSURE LINE AND ELECTRICAL CONDUIT ALONG NOSE

MODEL SCALE = .006

DRAWING NUMBER: VL78-000062B

DIMENSIONS: (INCHES)	THEORETICAL FULL-SCALE	THEORETICAL MODEL SCALE	A AL SURED MODEL SCALE
HEIGHT	6.67	.04	
WIDTH	10.00	.06	
X_T (BEGINNING)	360.92	2.165	
X_T (ENDING)	4.805	800.92	
RADIAL POSITION	33.45°	32°42'	

TABLE III. (Continued)

MODEL COMPONENT: CENTER BODY AND BASE PROTUBERANCE NUMBER 2

GENERAL DESCRIPTION: LO_2 FEED LINE

MODEL SCALE = .006

DRAWING NUMBER: VL78-000062B

DIMENSIONS: (INCHES)	THEORETICAL FULL-SCALE	THEORETICAL MODEL SCALE	ACTUAL MEASURED MODEL SCALE
HEIGHT	16.67	.1	
WIDTH	16.67	.1	
X_T (BEGINNING)	1040	6.24	
X_T (ENDING)	2052	12.312	
RADIAL POSITION	23°24'	23°24'	

TABLE III. (Continued)

MODEL COMPONENT: CENTER BODY AND BASE PROTUBE...CE NUMBER 3

GENERAL DESCRIPTION: ELECTRICAL CONDUIT, LO_2 RECIRCULATION LINE AND LO_2 PRESSURE LINE

MODEL SCALE = .006

DRAWING NUMBER: VL78-000062B

DIMENSIONS: (INCHES)	THEORETICAL FULL-SCALE	THEORETICAL MODEL SCALE	ACTUAL MEASURED MODEL SCALE
HEIGHT	6.67	.040	
WIDTH	19.0	.114	
X_T (BEGINNING)	1040	6.24	
X_T (ENDING)	2052	12.312	
RADIAL POSITION	33°45'	34°16'	

TABLE III. (Continued)

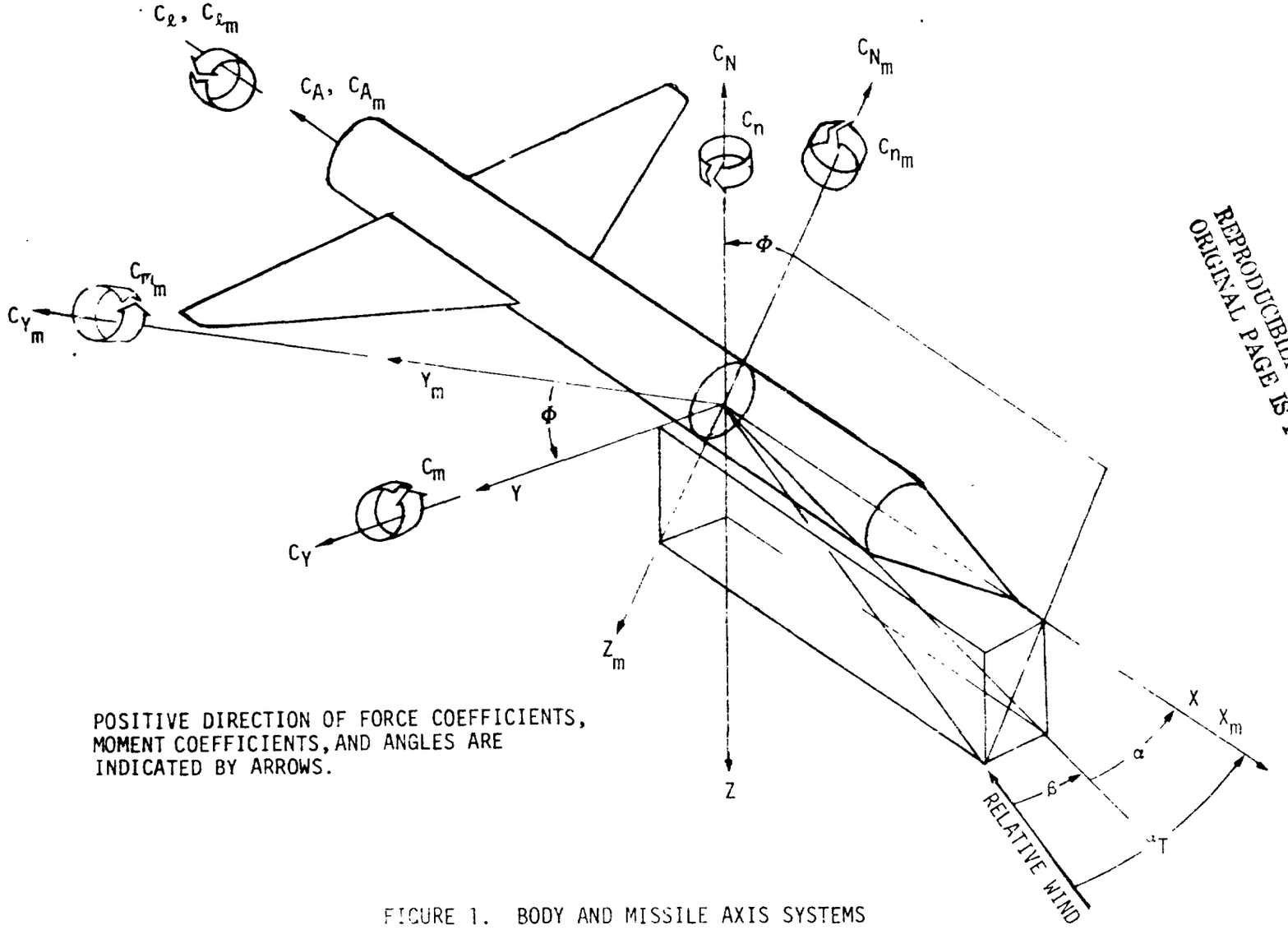
MODEL COMPONENT: ATTACH STRUCTURE

GENERAL DESCRIPTION: AFT SRB/ET ATTACH STRUCTURE (3 MEMBERS, ET PORTION TESTED ONLY)

MODEL SCALE = .006

DRAWING NUMBER: VL78-000062B

DIMENSIONS: (INCHES)	THEORETICAL FULL-SCALE	THEORETICAL MODEL SCALE	ACTUAL MEASURED MODEL SCALE
LOWER HORIZONTAL MEMBER			
X_T	2052	12.312	
Y_T	±161.32	±.968	
Z_T	-57	-.342	
DIAMETER	5.5	.033	
UPPER HORIZONTAL MEMBER			
X_T	2052	12.312	
Y_T	+161.32	+.968	
Z_T	57	.342	
DIAMETER	5.5	.033	
UPPER VERTICAL MEMBER			
X_T	2052	12.312	
Y_T	±161.32	±.968	
Z_T	57	.342	
DIAMETER	5.5	.033	



POSITIVE DIRECTION OF FORCE COEFFICIENTS, MOMENT COEFFICIENTS, AND ANGLES ARE INDICATED BY ARROWS.

FIGURE 1. BODY AND MISSILE AXIS SYSTEMS

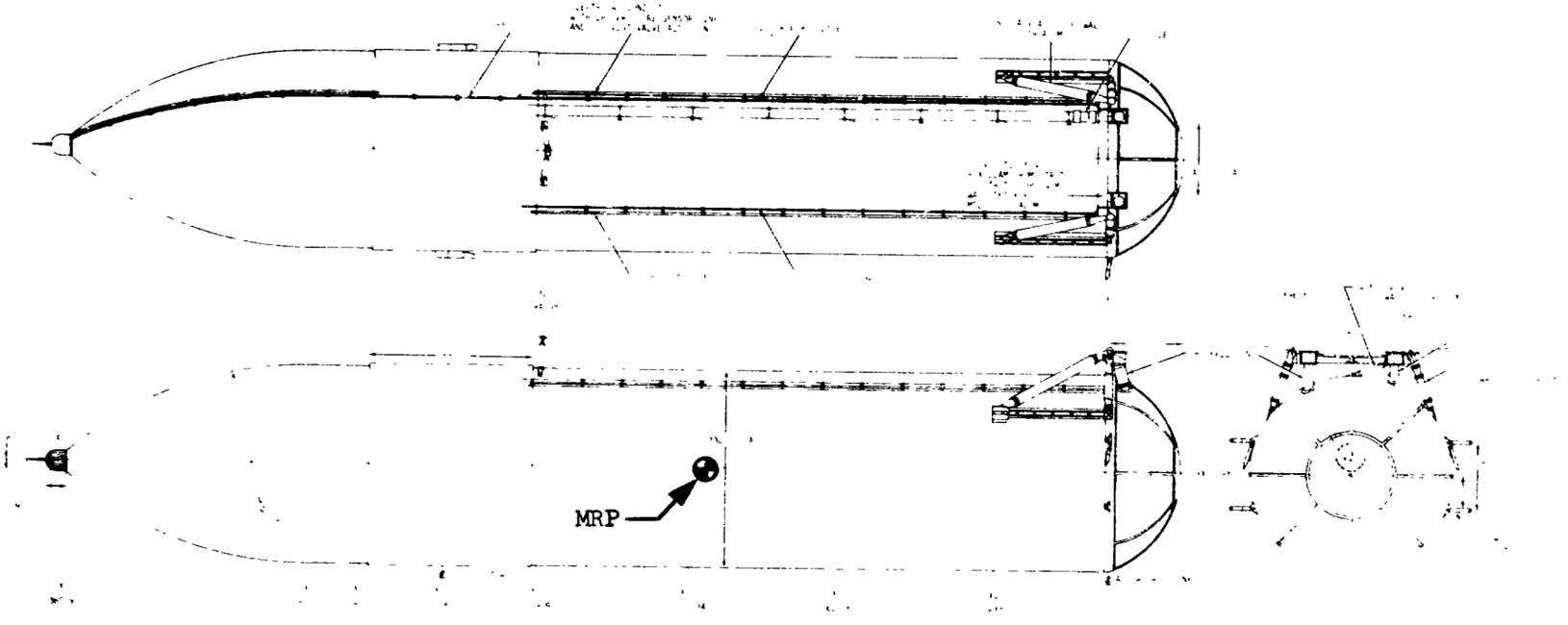


FIGURE 2a. CONFIGURATI DEFINITION FROM ROCKWELL DRAWING VL78-000062B

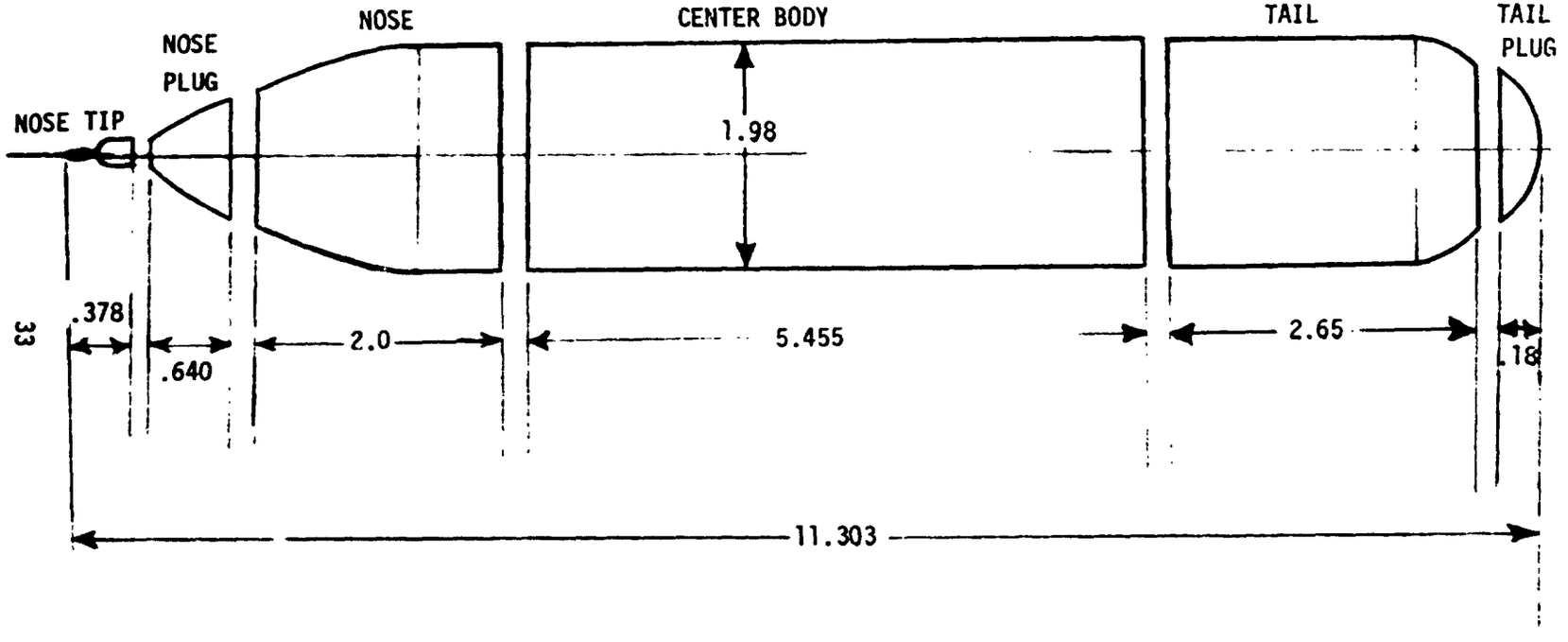
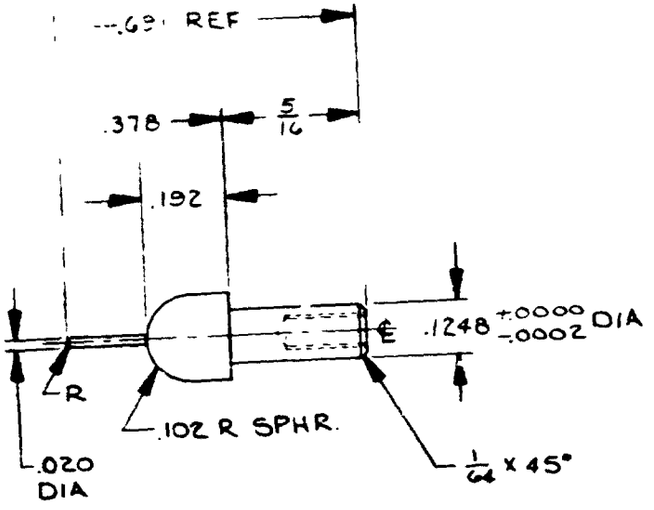
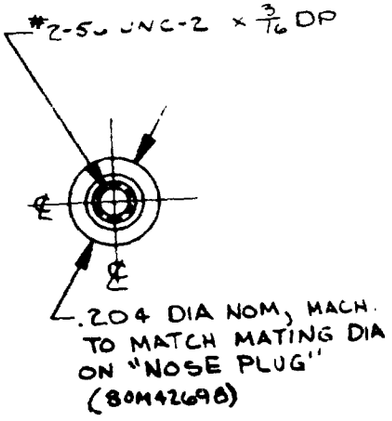


FIGURE 2b. SIC EL PARTS AND DI NSI S

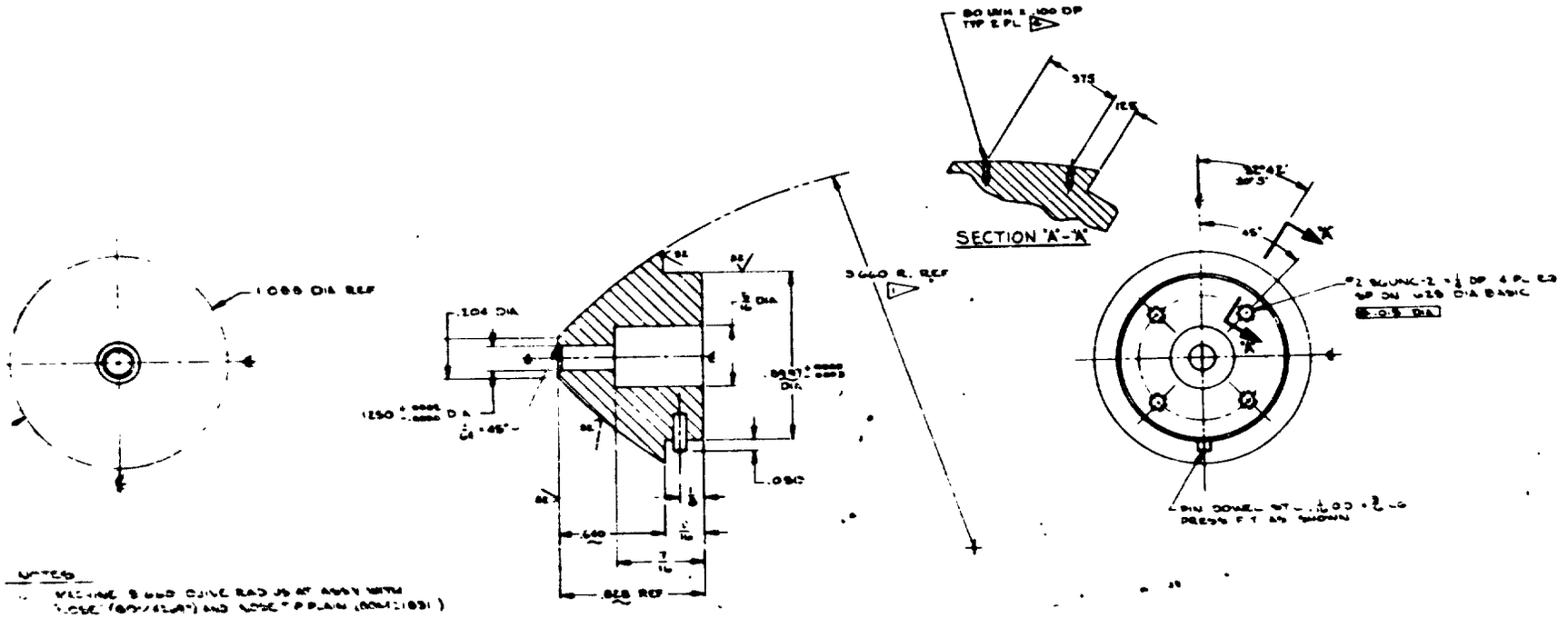




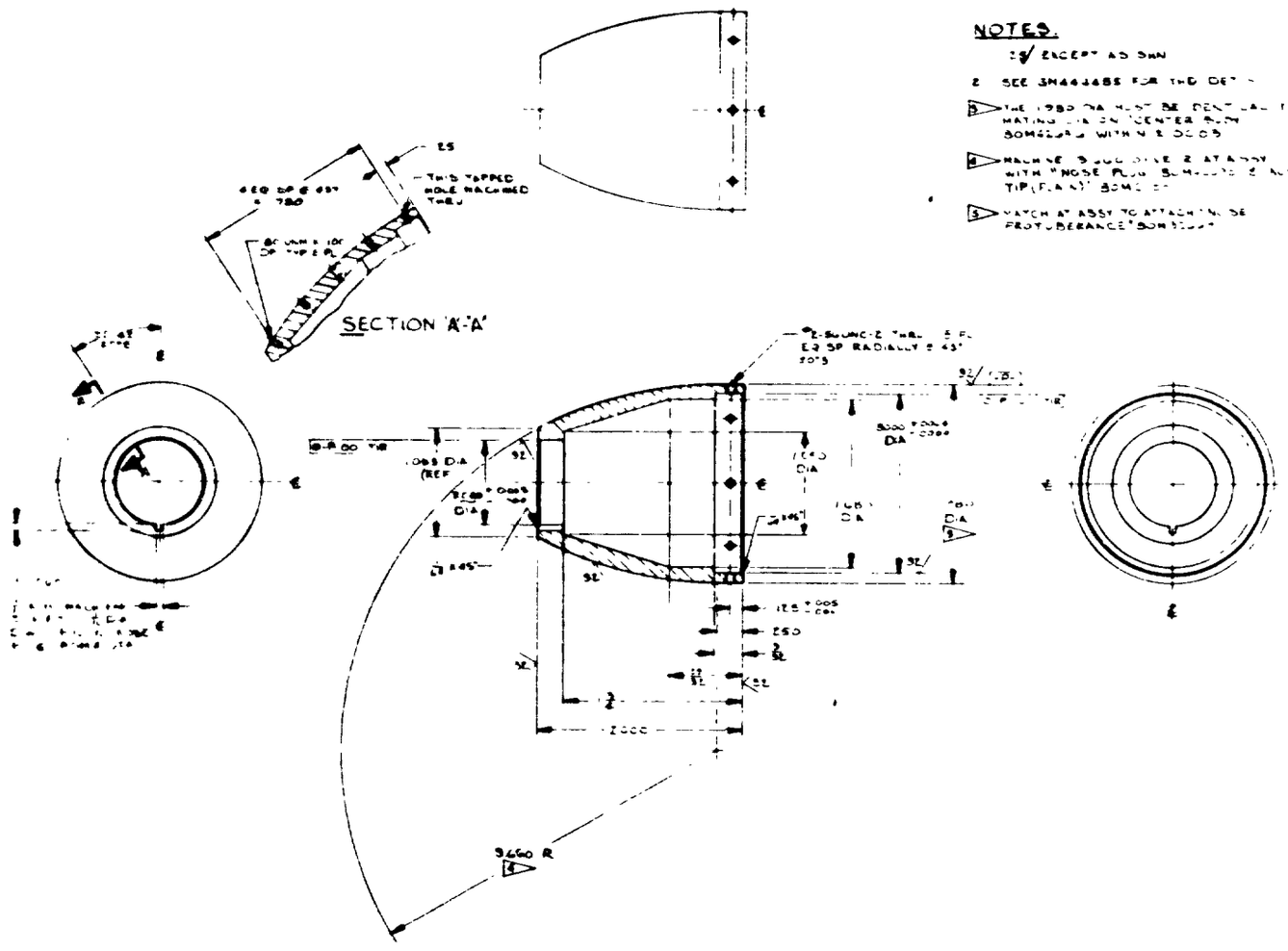
NOTES:

1. 32√
2. SEE GM444455 FOR THD DET'S.

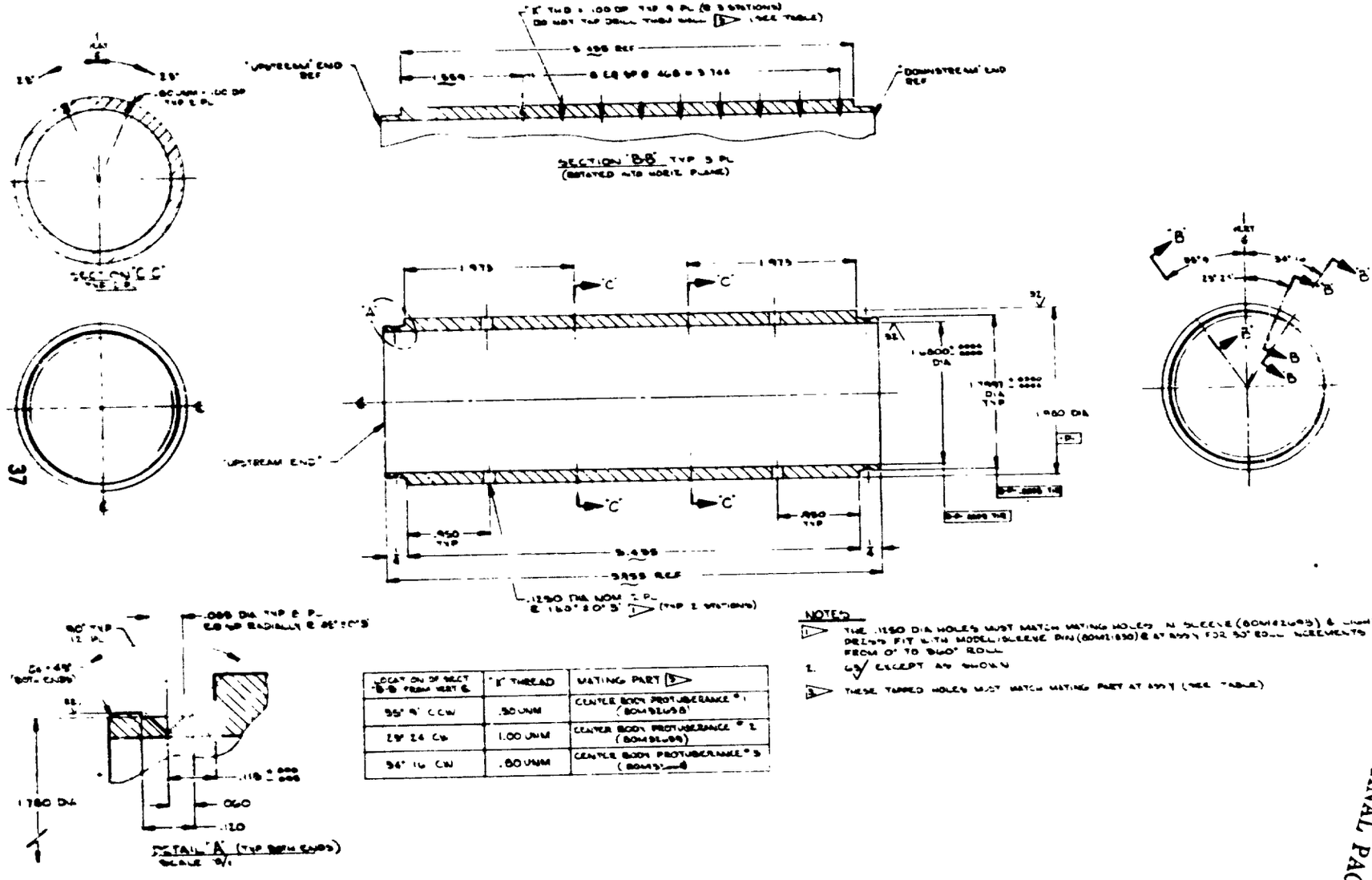
FI 2c. L NOSE TIP



FI 2d. L SE PL



FI 2e. DEL NOSE



LOCATION OF SECT 'B-B' FROM VERT ℄	'℄' THREAD	MATING PART ▷
95° 9' CCW	.50 UNM	CENTER BODY PROTUBERANCE ° 1 (BOM 81498)
29° 24' CW	1.00 UNM	CENTER BODY PROTUBERANCE ° 2 (BOM 81499)
94° 16' CW	.80 UNM	CENTER BODY PROTUBERANCE ° 3 (BOM [illegible])

NOTES:

▷ THE .1250 DIA HOLES MUST MATCH MATING HOLES IN SLEEVE (BOM 82693) & LIGHT DRIVE FIT WITH MODEL/SLEEVE PIN (BOM 81650) @ ANY 5° FOR 30° ROLL INCREMENTS FROM 0° TO 360° ROLL

1. 63√ EXCEPT AS SHOWN

▷ THESE TAPPED HOLES MUST MATCH MATING PART AT ANY (SEE TABLE)

FI 2f. L C ER Y FOR SE D TAIL

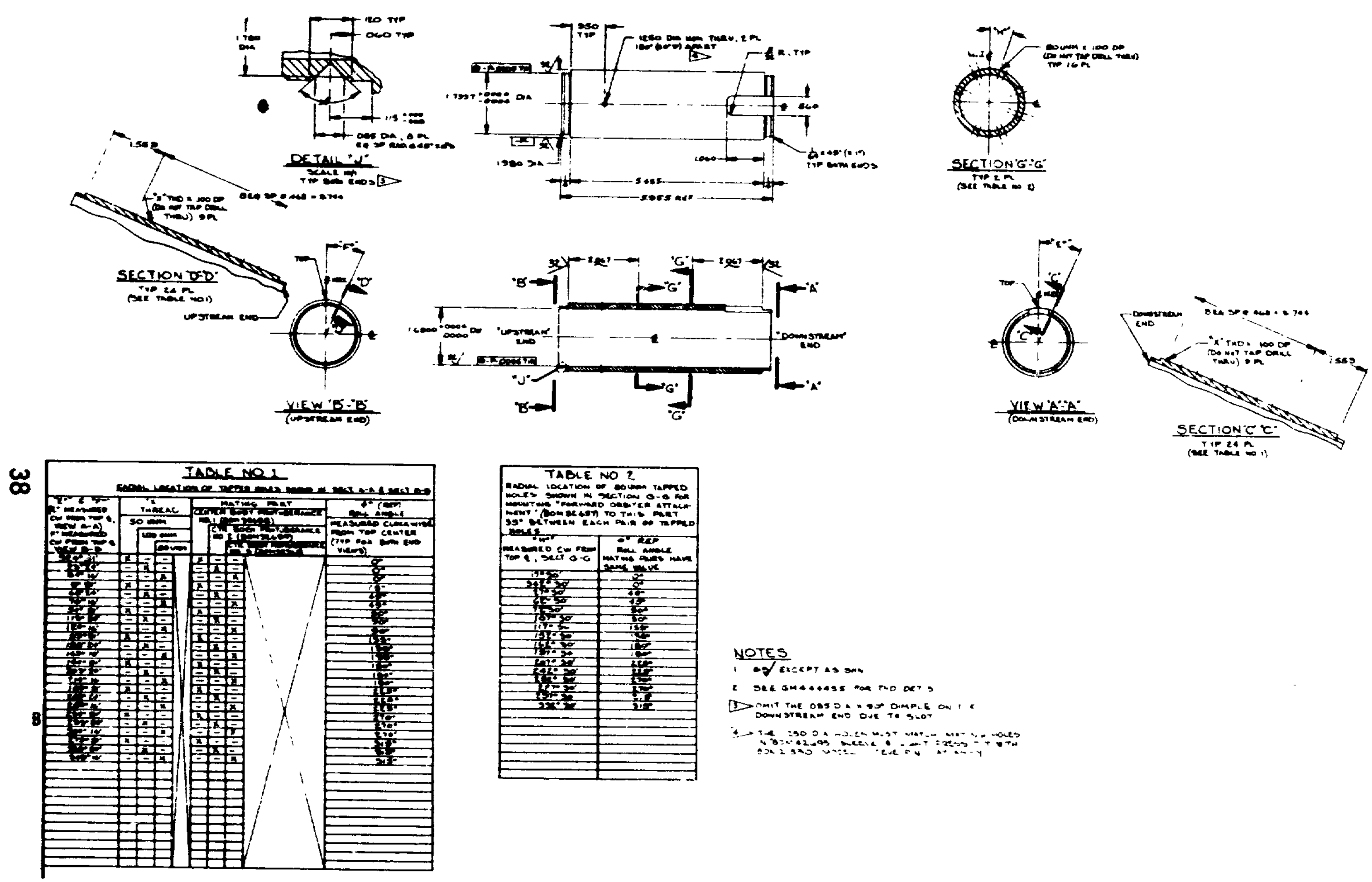


FIGURE 2g. MODEL CENTER BODY FOR SIDE MOUNT

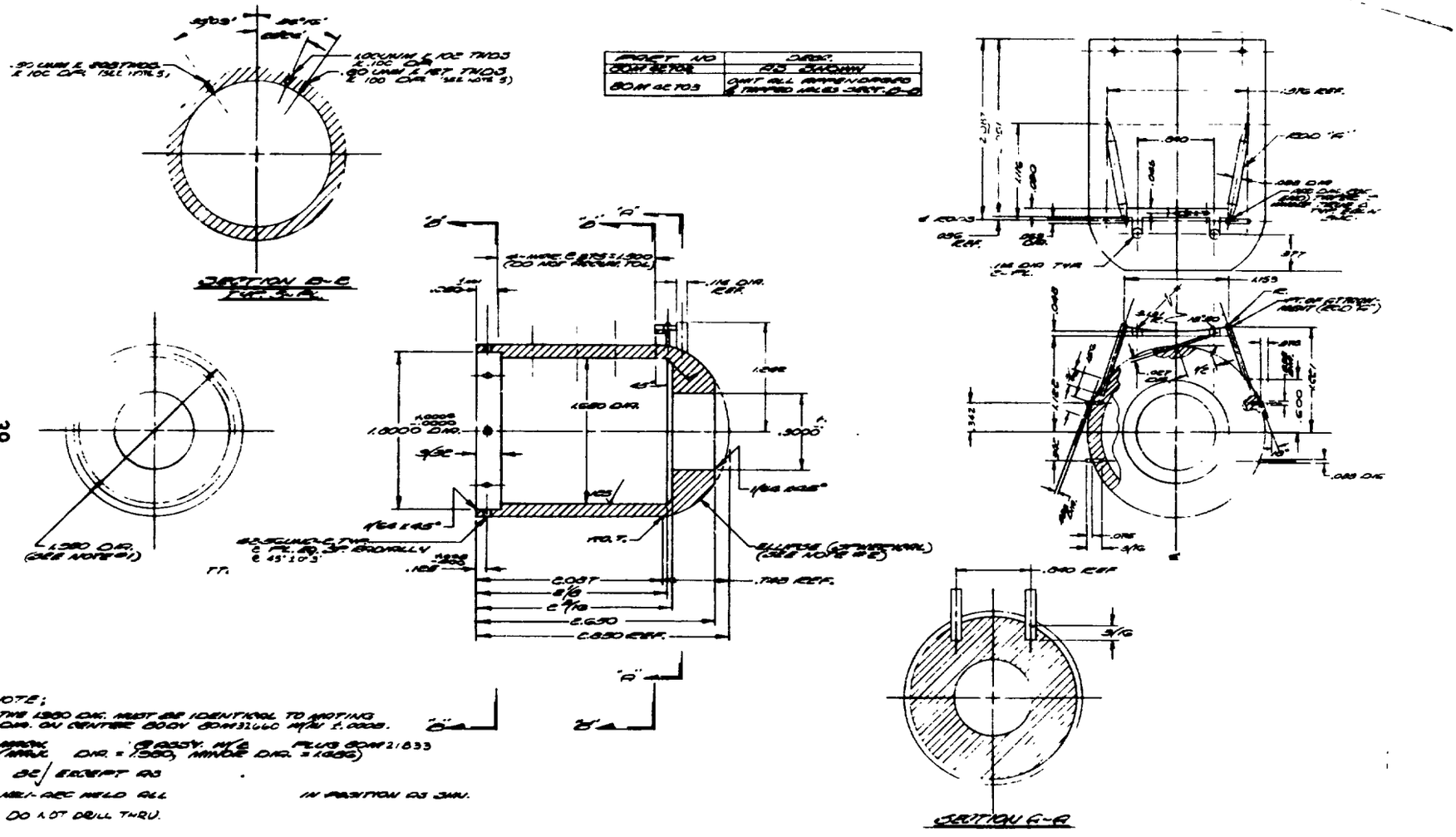
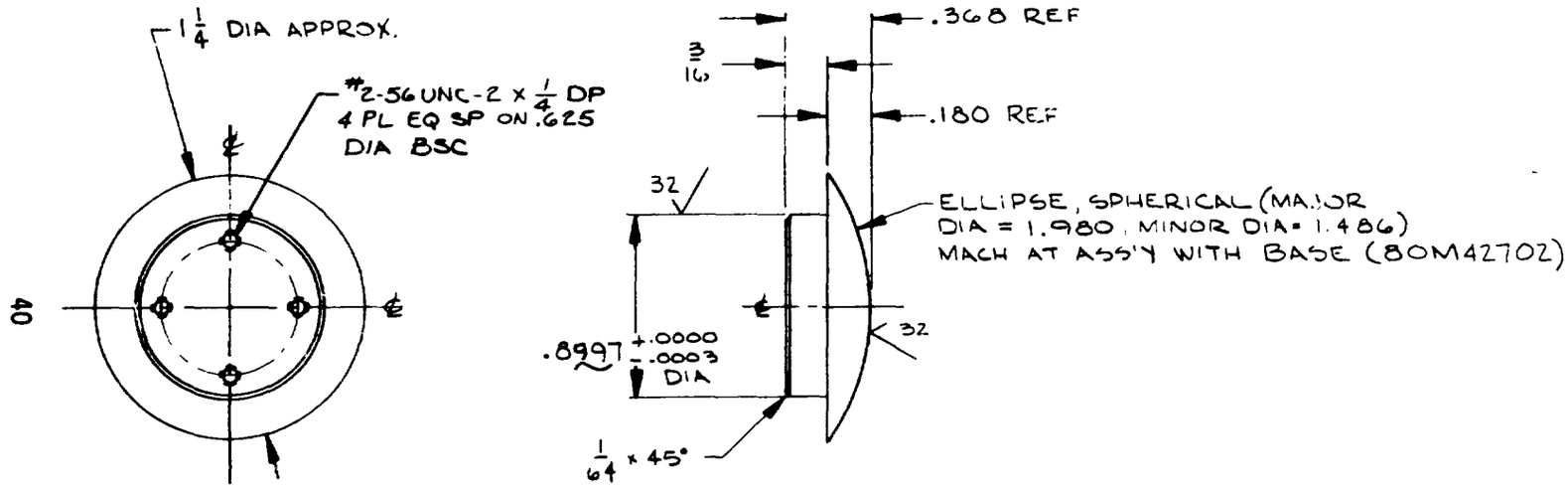


FIGURE 2h. DEL BASE



NOTES

1. 63 EXCEPT AS SHOWN.
2. SEE GM444455 FOR TH'D DET'S.

FIGURE 2i. MODEL BASE PLUG

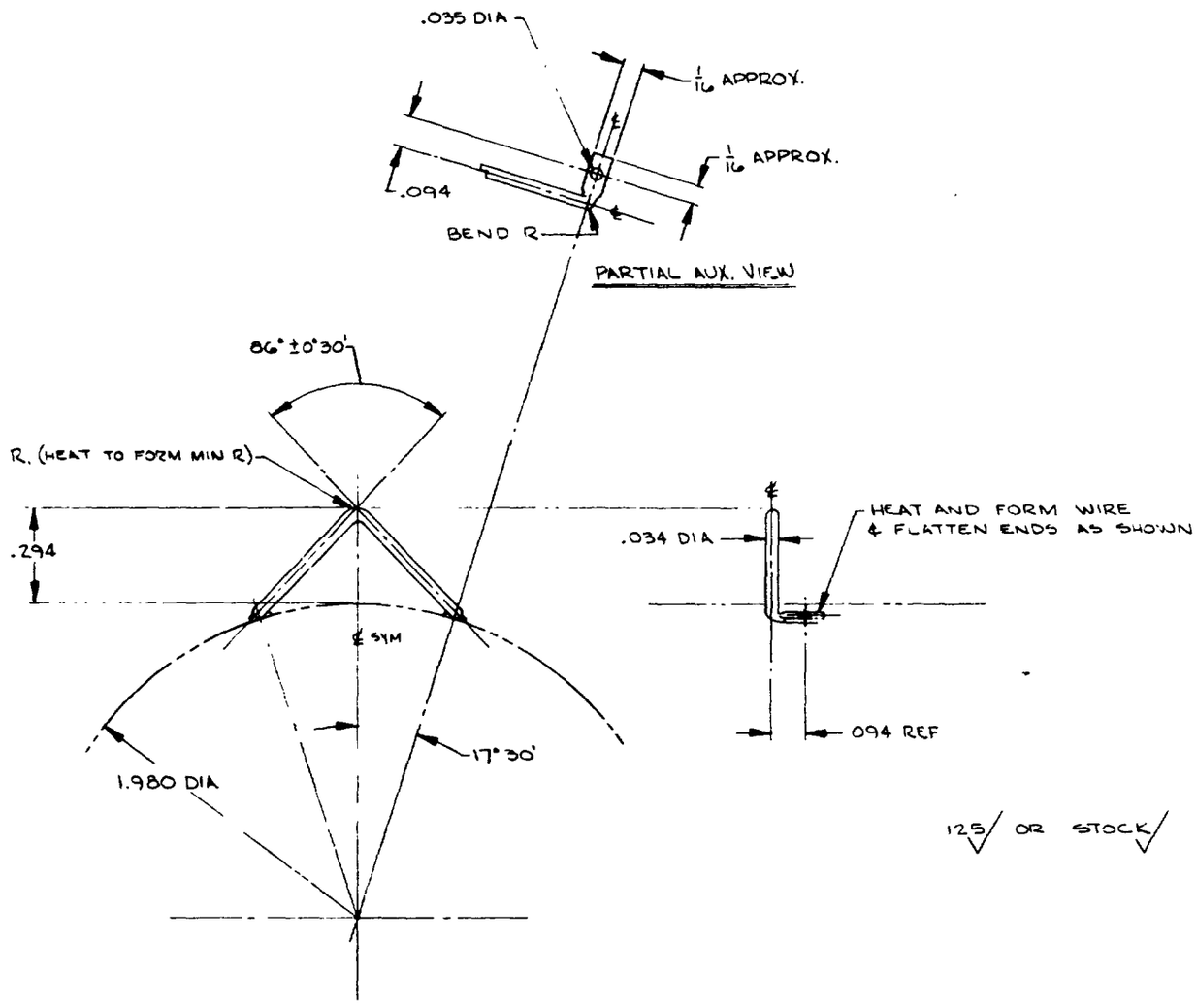


FIGURE 2j. FOR RD ORBITER ATTACH HARDWARE

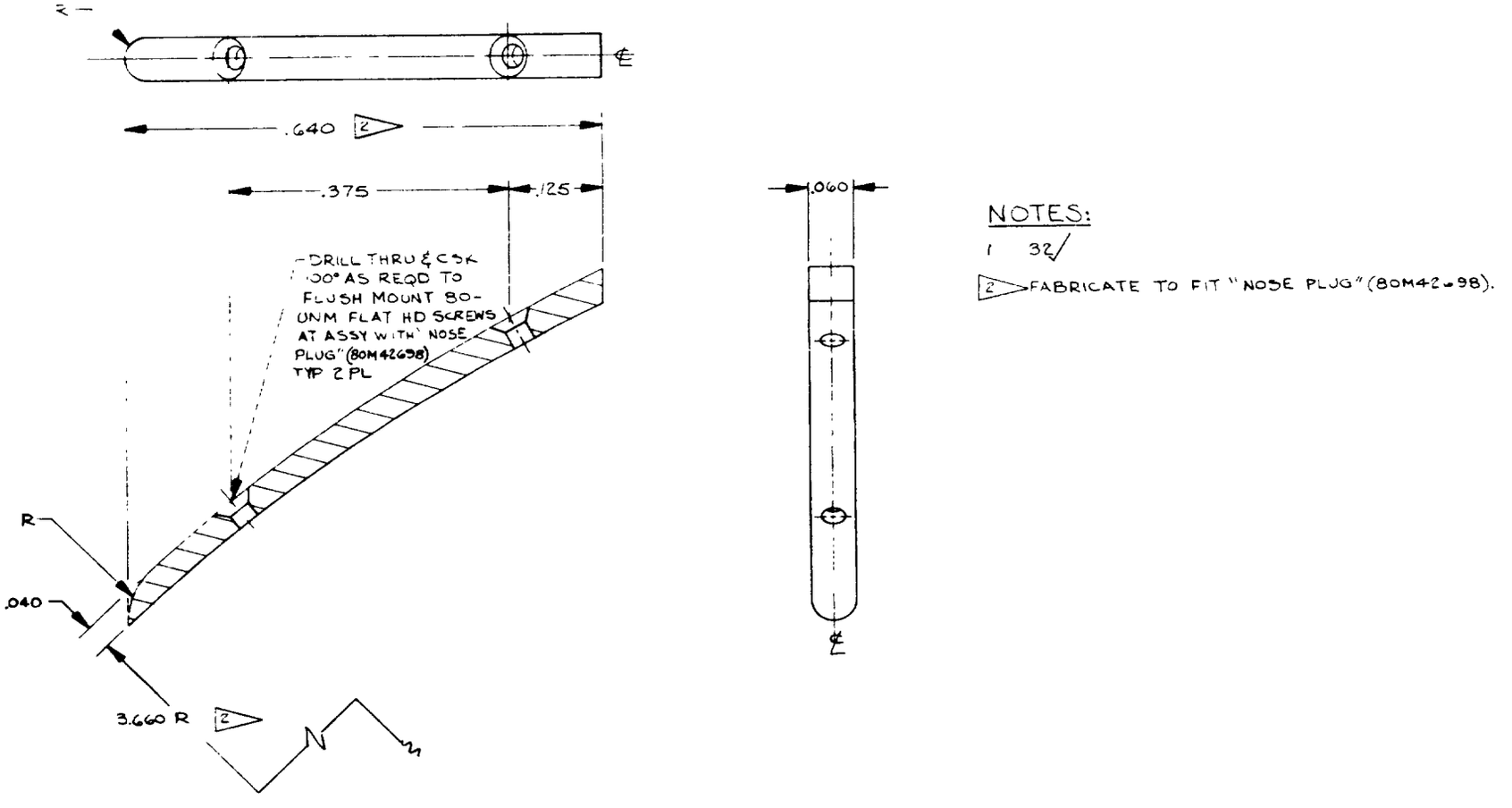


FIGURE 2k. ELECTRICAL CONDUIT NOSE PLUG PROTUBERANCE

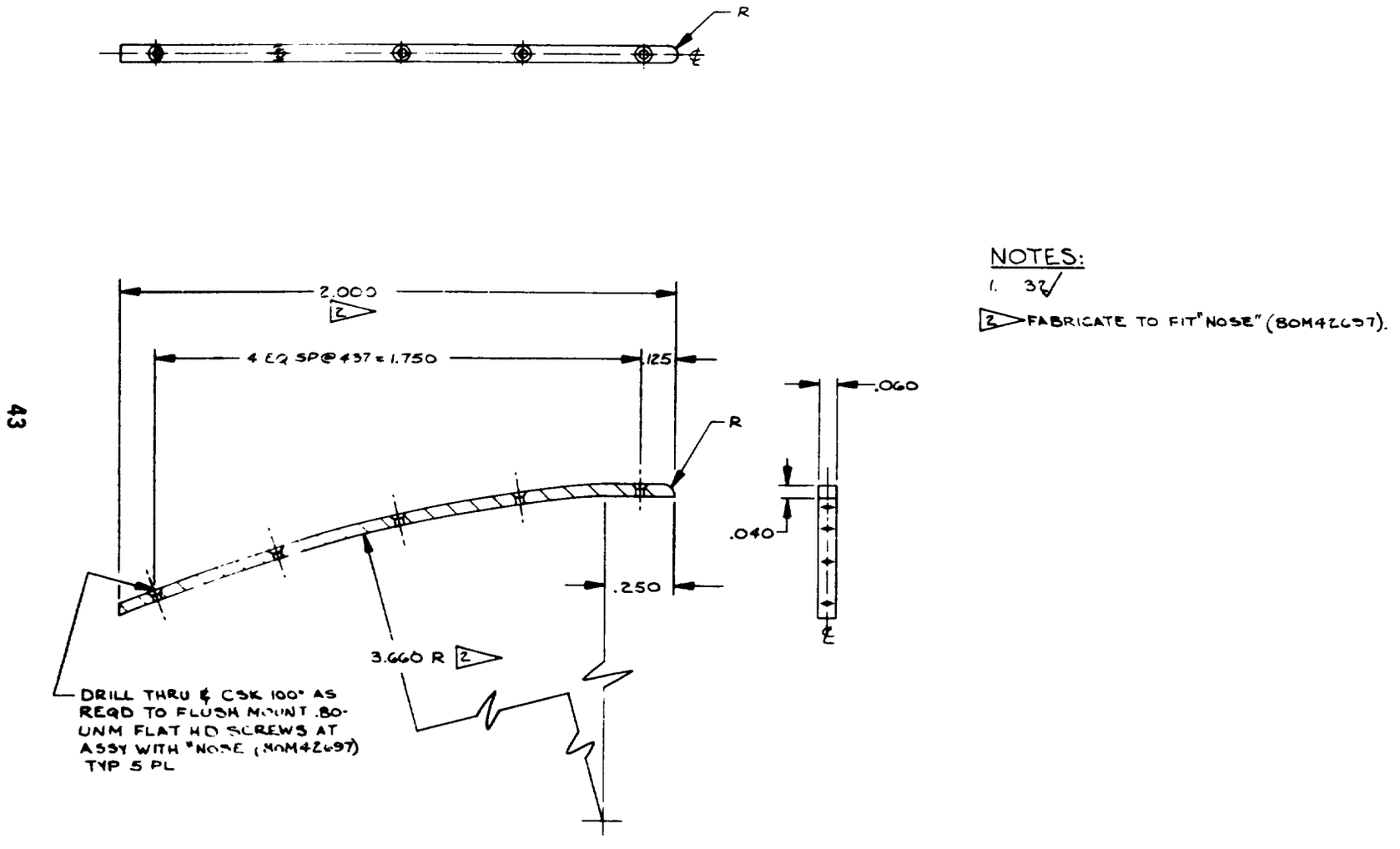
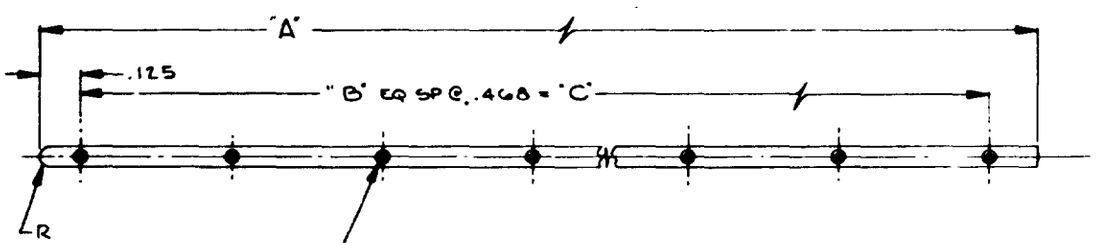
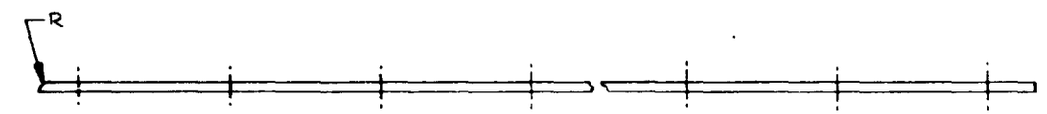
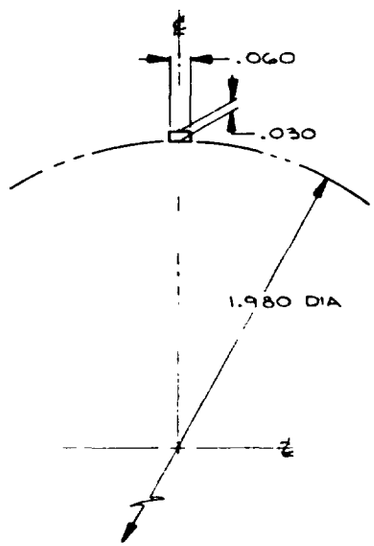


FIGURE 21. ELECTRICAL CONDUIT NOSE PROTUBE CE

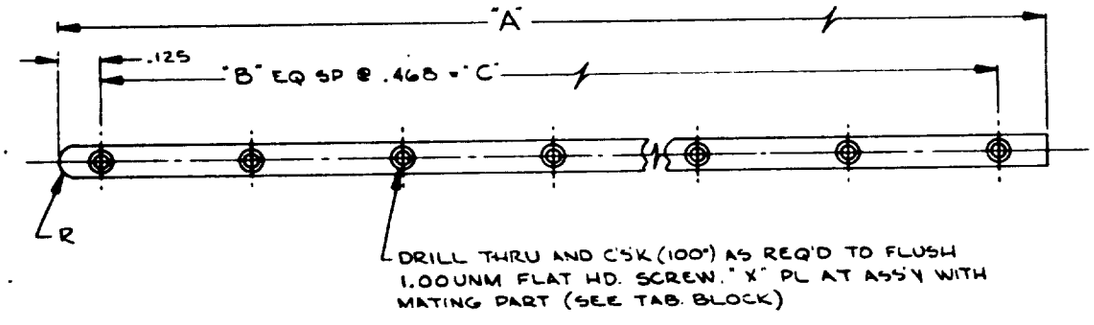


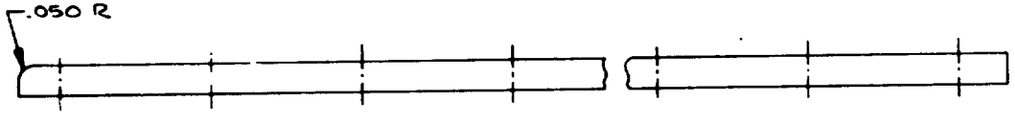


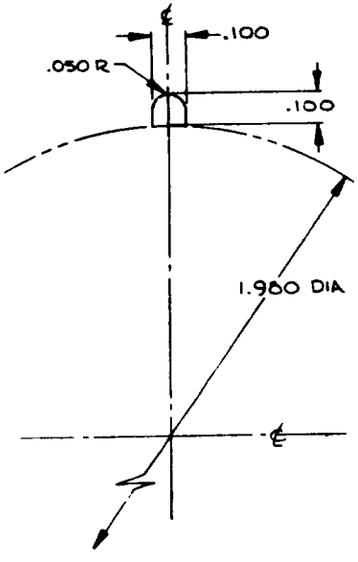


PART NO	"A"	"B"	C	"X"	DESIGNATION	MATING PART
80M32658	4.021	8	3.744	9 PL	# 1	CENTER BODY, 80M42696 & CENTER BODY 90° 80M51363
80M32661	2.961	6	2.933	7 PL	# 1-A	CENTER BODY, 90° 80M51363

FIGURE 2m. LH_2 PRESSURE LINE PROTUBERANCE

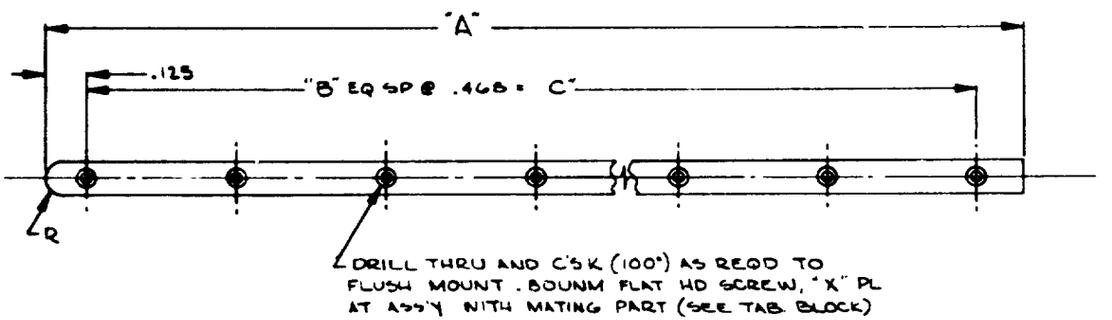


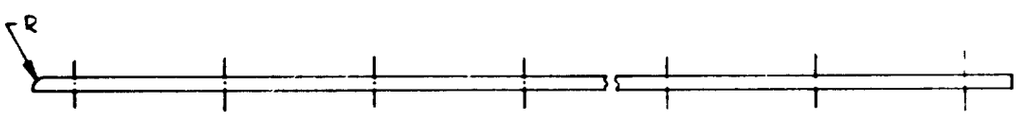




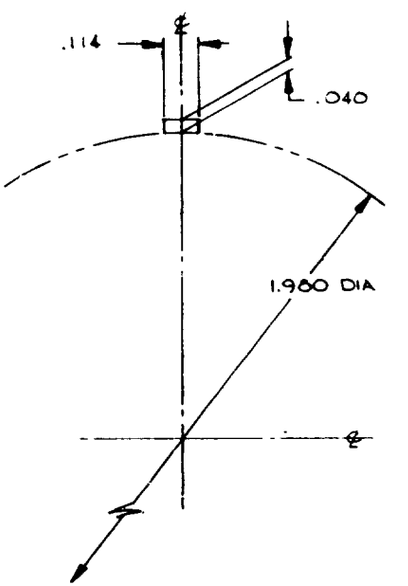
PART NO.	"A"	"B"	"C"	"X"	DESIGNATION	MATING PART
BOM32659	4.021	8	3.744	9 PL	*2	CENTER BODY, BOM42696 & CENTER BODY, 90° BOM51363
BOM32662	2.961	6	2.933	7 PL	*2-A	CENTER BODY, 90° BOM51363

FIGURE 2n. LO_2 FEED LINE PROTURE CE



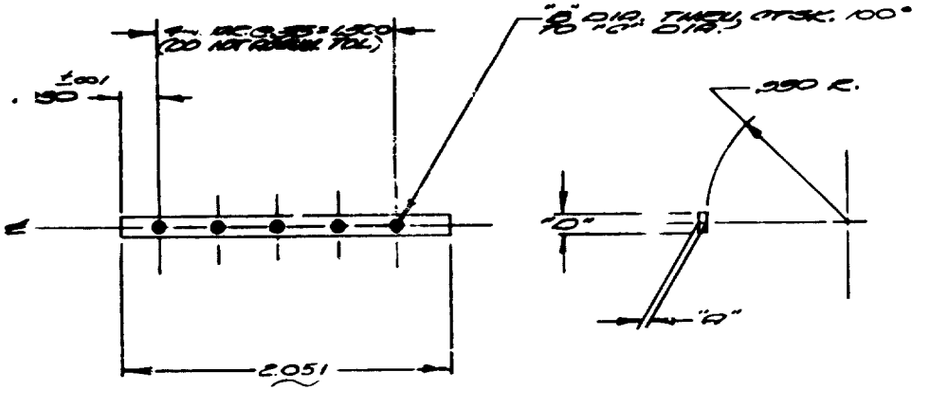


32



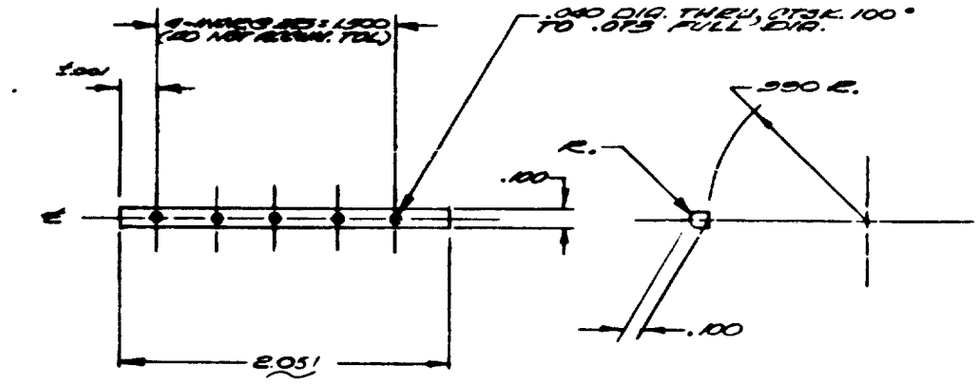
PART NO.	"A"	"B"	"C"	"X"	DESIGNATION	MATING PART
80M32660	4.021	8	3.744	9 PL	* 3	CENTER BODY, 80M42696 & CENTER BODY, 90° 80M51363
80M32663	2.961	6	2.933	7 PL	* 3-A	CENTER BODY, 90°, 80M51363

FI 2o. LO_2 P SSURE LINE, LO_2 RECIRCULATI LINE AND ELECTRICAL CONDUIT PROTUBE CE



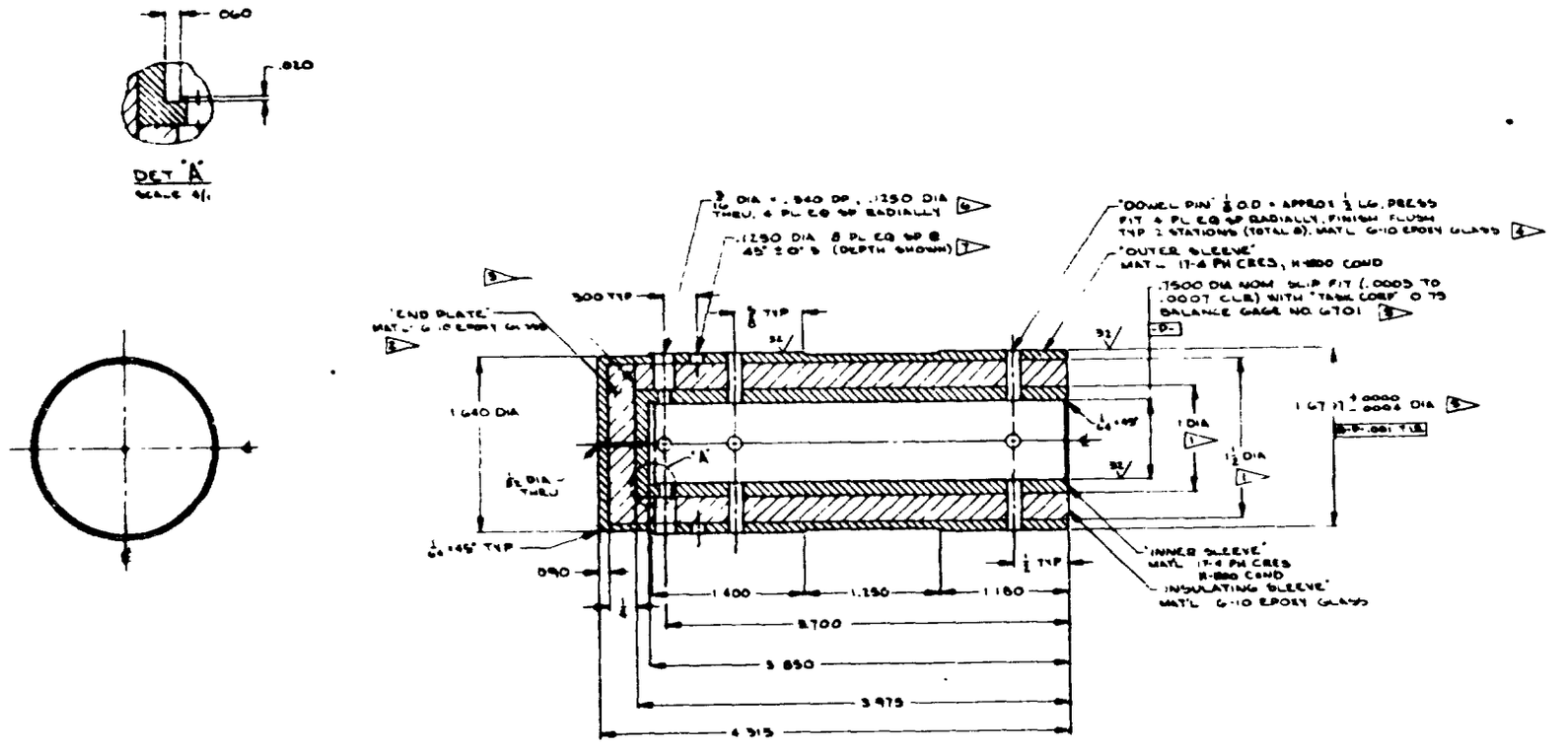
PART NO.	"B"	"C"	"D"	"E"	NO.
[illegible]	.090	.020	.086	.060	1
[illegible]	.040	.093	.037	.114	3

FI 2p. LH_2 P S LINE P TUBE E D LO_2 P SSURE LINE,
LO_2 CIRCULATI LINE D ELECTRICAL C IT PROTUBE CE



3c

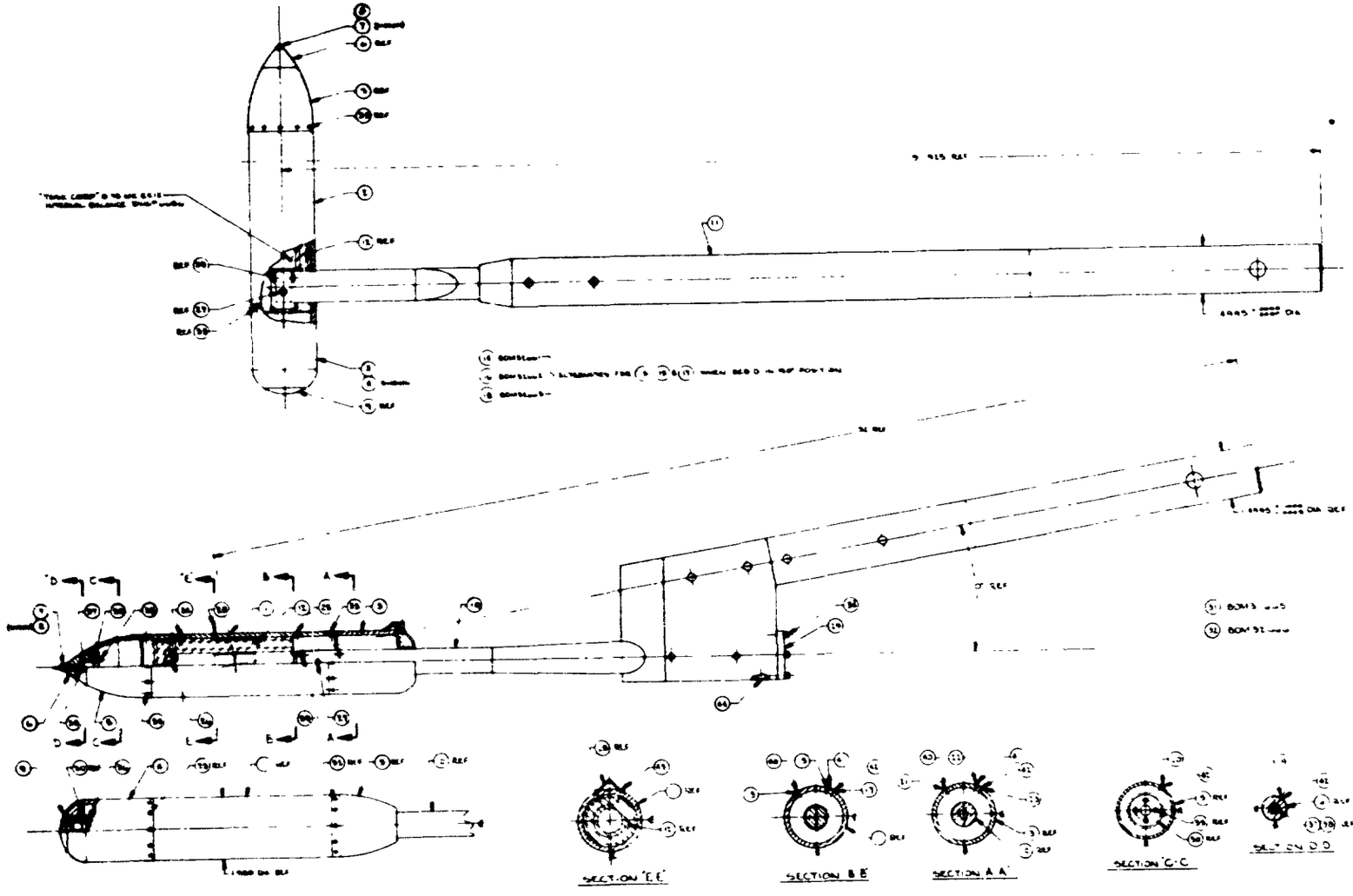
FI 2q. E P TION OF LO_2 FEED LINE PROTUBE CE



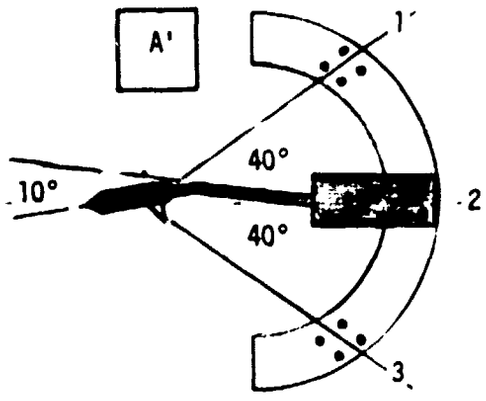
NOTES

1. MACHINE 'INNER SLEEVE' & 'OUTER SLEEVE' AS REQD FOR PRESS FIT WITH 1½ O.D. × 1 I.D. COMMERCIAL G-10 EPOXY GLASS
2. MACHINE ¼ THICK G-10 EPOXY GLASS END PLATE FOR PRESS FIT WITH 'OUTER SLEEVE'
3. COAT MATING SURFACES BETWEEN 'END PLATE' & INSULATING SLEEVES WITH HI-TEMP EPOXY PRIOR TO POSITIONING
4. PRESS PARTS TOGETHER & DOWEL PIN AS SHOWN
5. FINISH MACHINE PRECISION SURFACES AFTER PROPERLY FITTING & PINNING PARTS TOGETHER
6. THE .1250 DIA MUST MATCH MATING HOLES IN 'TANK CORP' 0 75 DIA BALANCE GAGE NO 6T01 & LIGHT PRESS FIT W/ .1245 BALANCE/SLEEVE PINS (BOM 21830) AT ASSY
7. THE .1250 C'B MUST MATCH MATING HOLES IN 'CENTER BODY (BOM 42696), 90° CENTER BODY' (BOM 81363) & LIGHT PRESS FIT WITH 'MODEL/SLEEVE PINS (BOM 21830) AT ASSY FOR 30° ROLL INCREMENTS FROM 0° TO 360° ROLL
8. AS' EXCEPT AS SHOWN

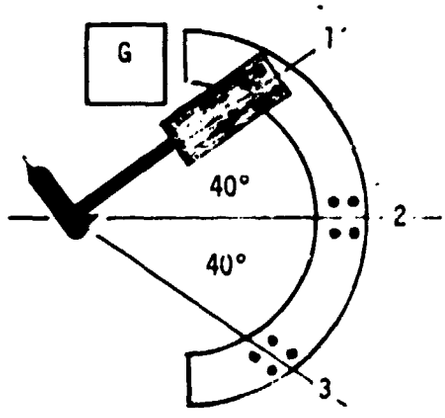
FI 2r. INSULATING SLEEVE



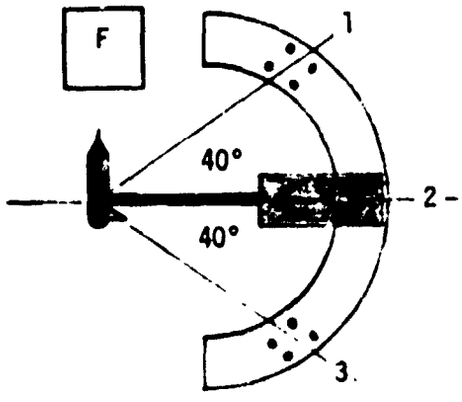
FI 2s. DEL ASSE LY ING



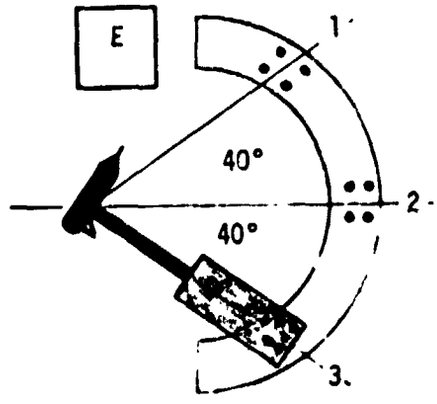
α = -5° to 30°



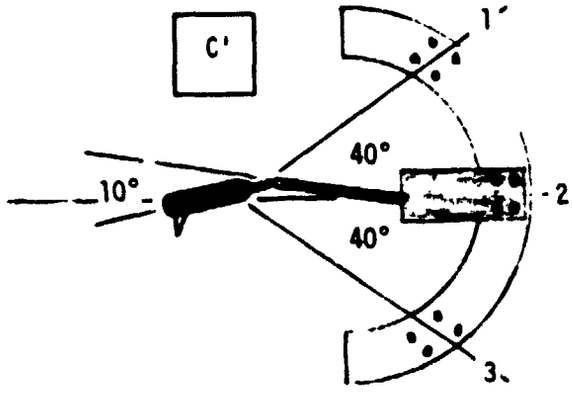
α = 30° to 65°



α = 70° to 105°



α = 110° to 145°



α = 150° to 185°

FI 2t. STRUT D L TING POSITIONS FOR LE-OF-ATTACK S

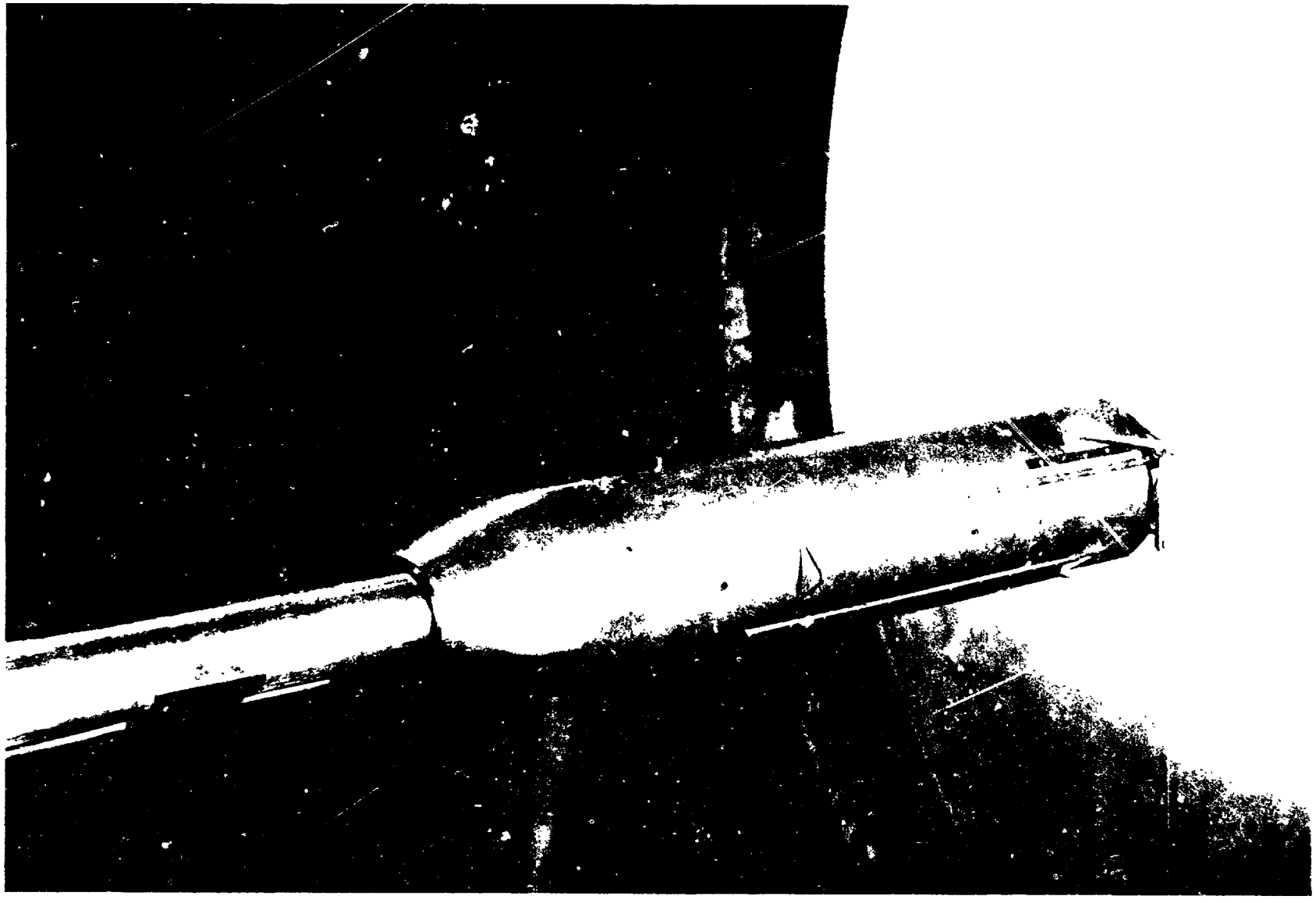


FIGURE 3a. TYPICAL TUNNEL INSTALLATION WITH MODEL MOUNTED FROM THE NOSE

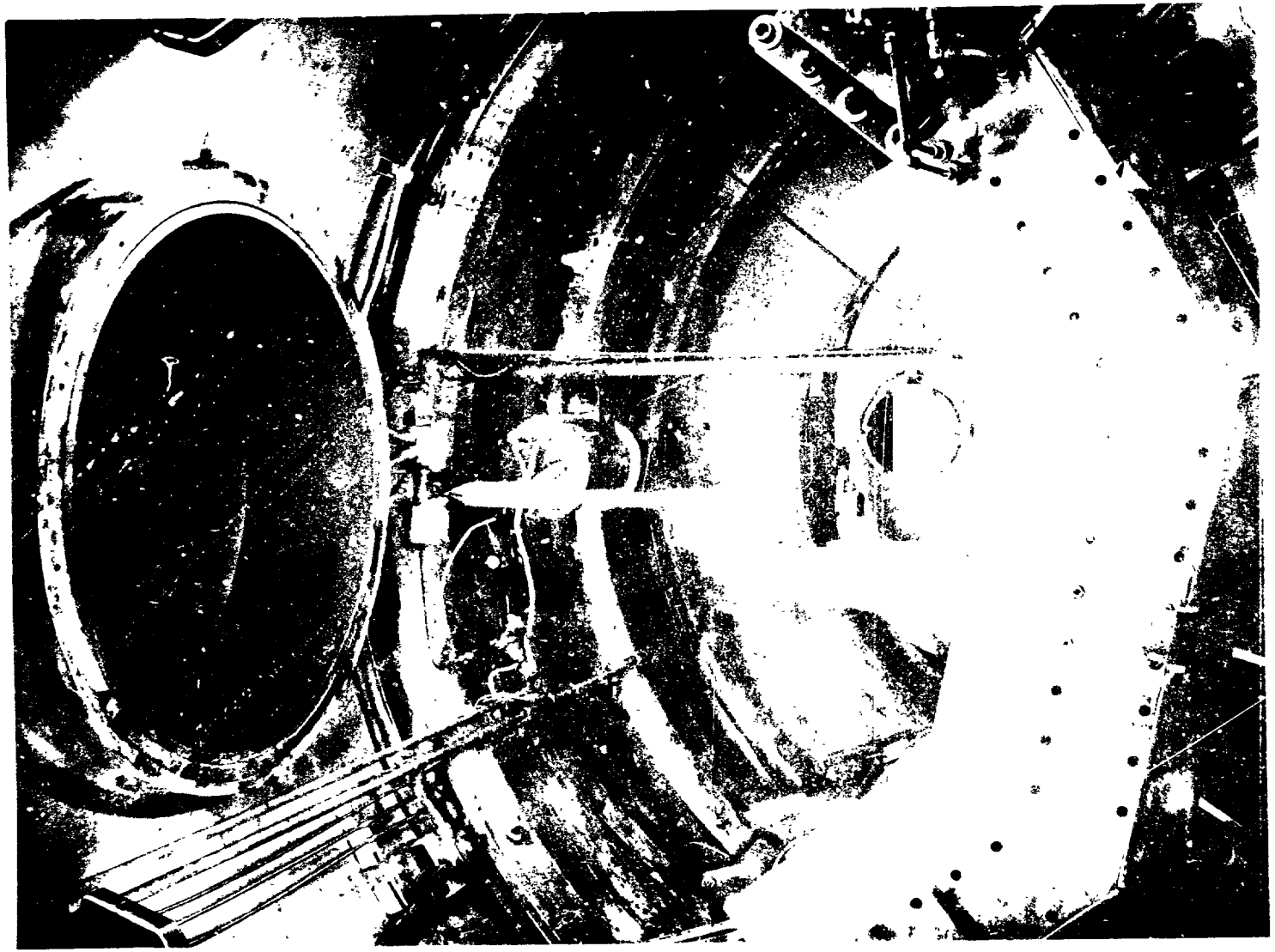


FIGURE 3b. TYPICAL TUNNEL INSTALLATION WITH MODEL MOUNTED FROM THE TAIL

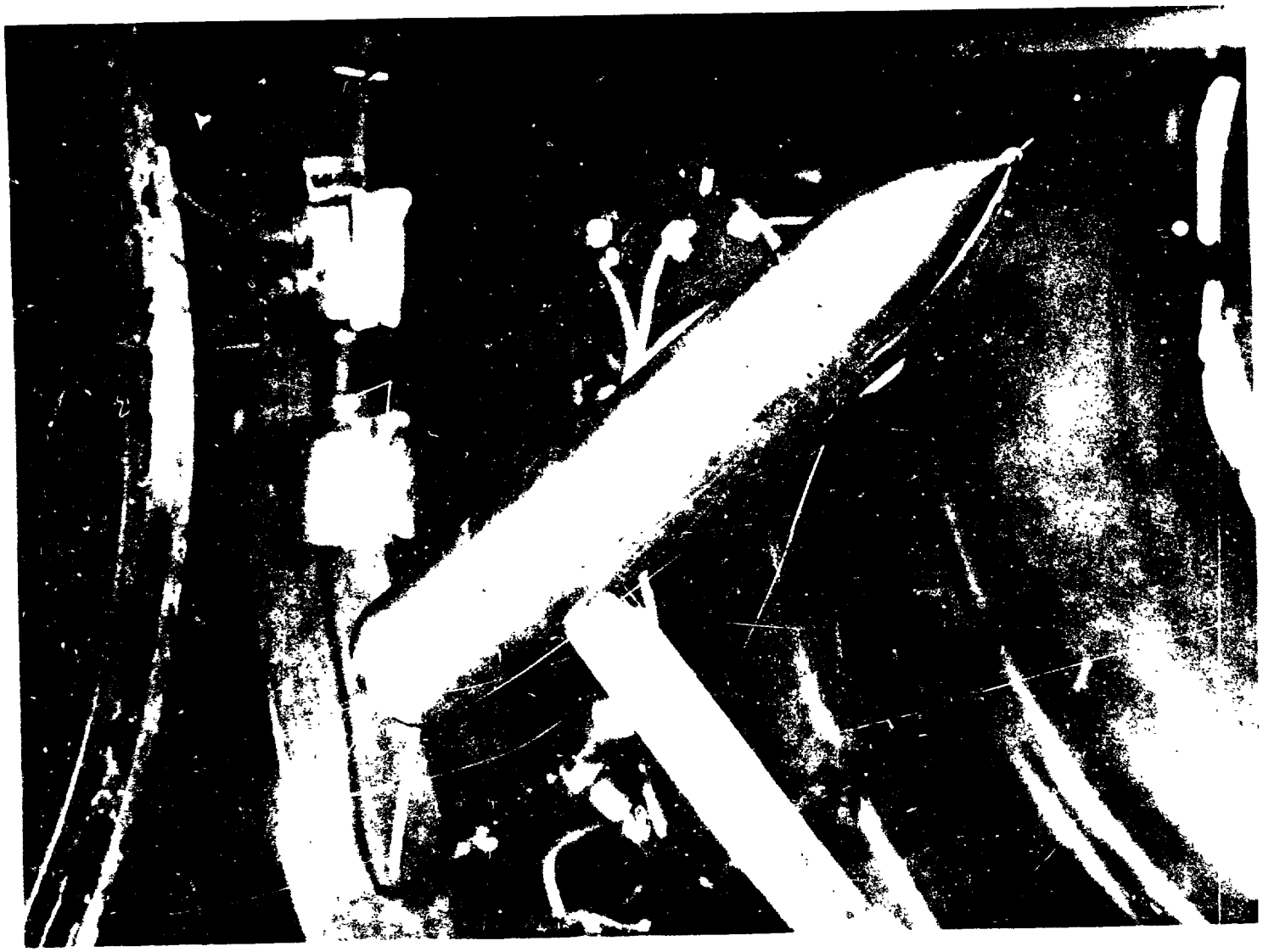


FIGURE 3c. TYPICAL TUNNEL INSTALLATION WITH MODEL MOUNTED FROM THE SIDE

DATA FIGURES

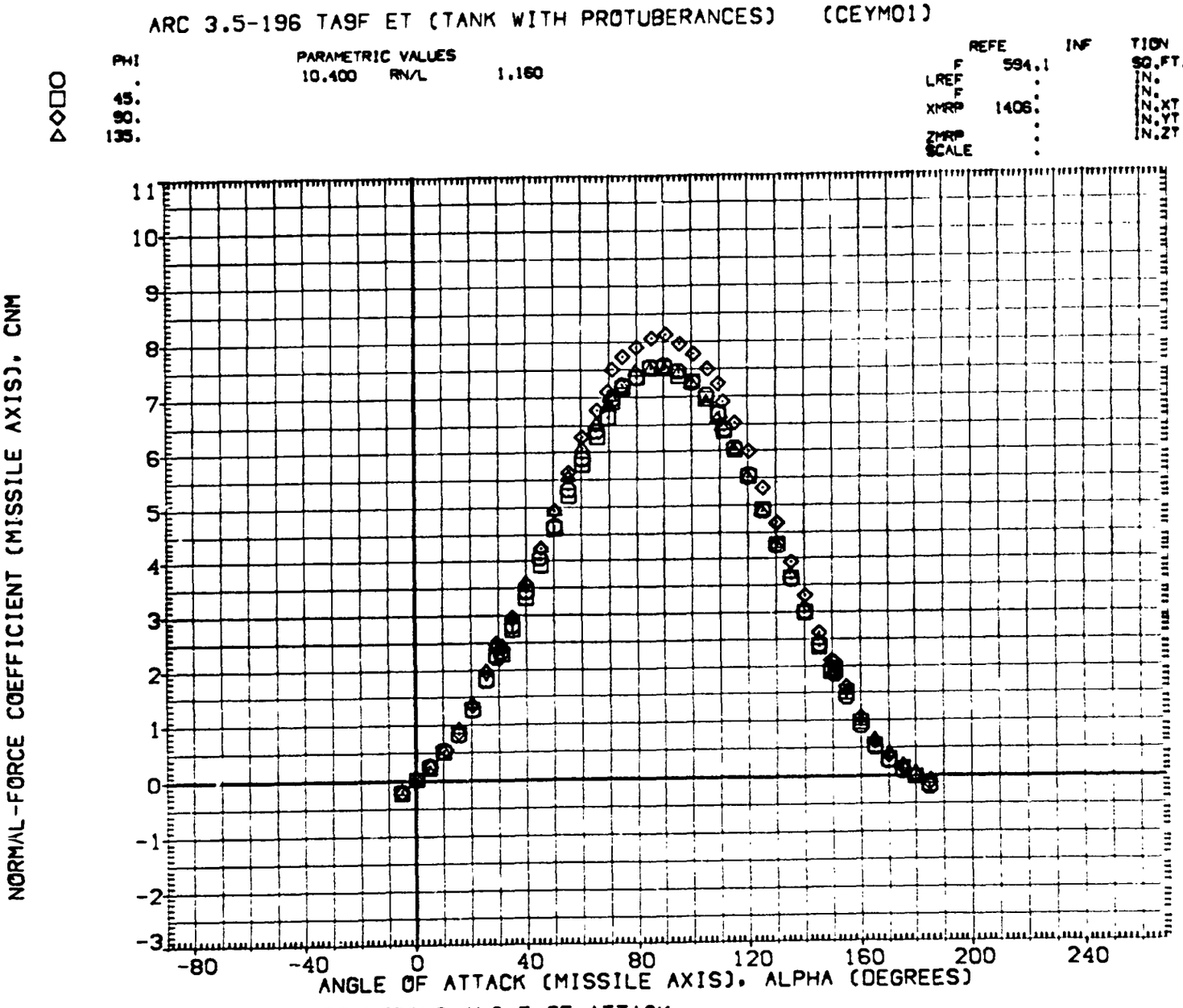


FIG. 4 COEFFICIENTS VERSUS ANGLE OF ATTACK

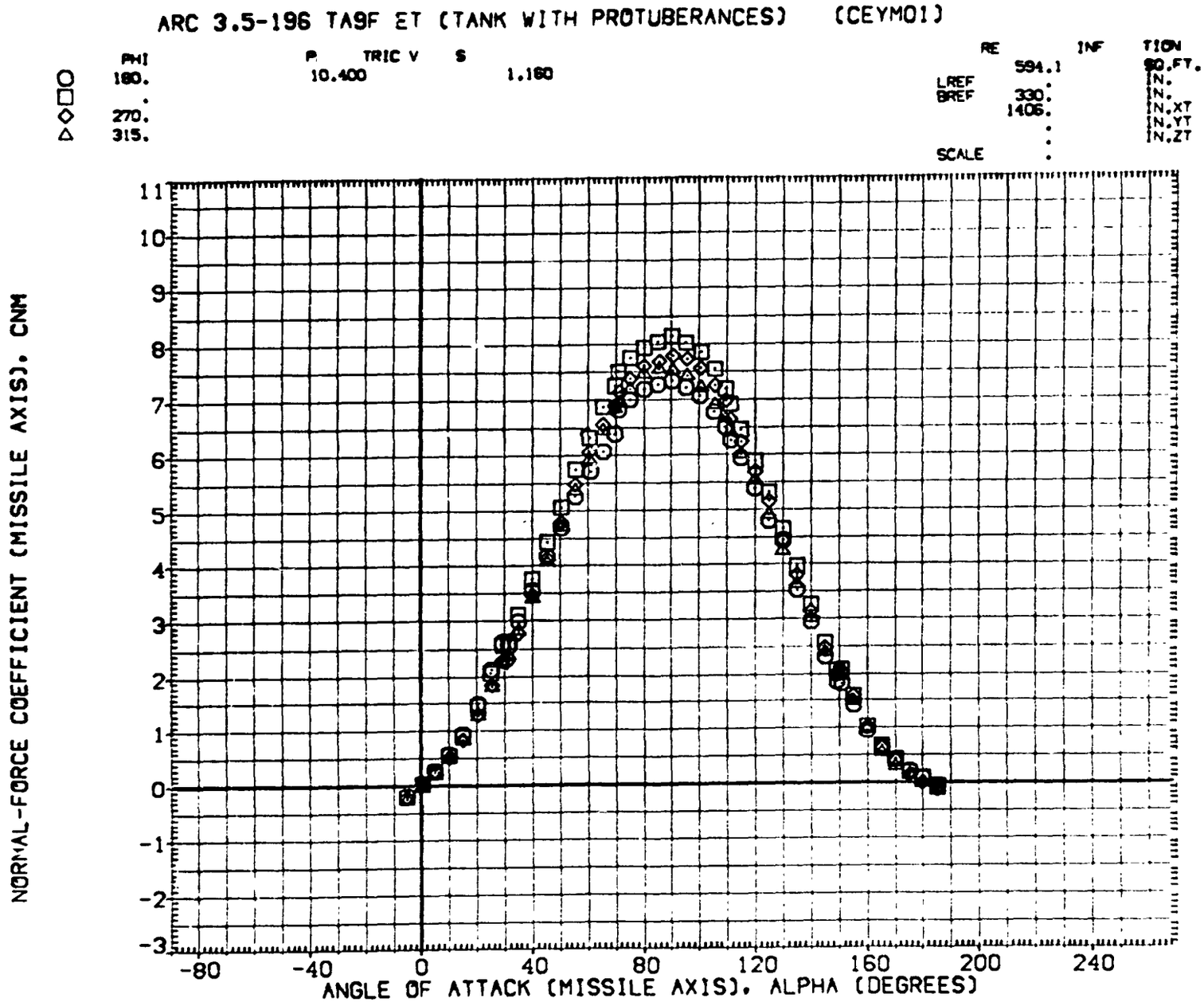


FIG. 4 COEFFICIENTS VERSUS ANGLE OF ATTACK

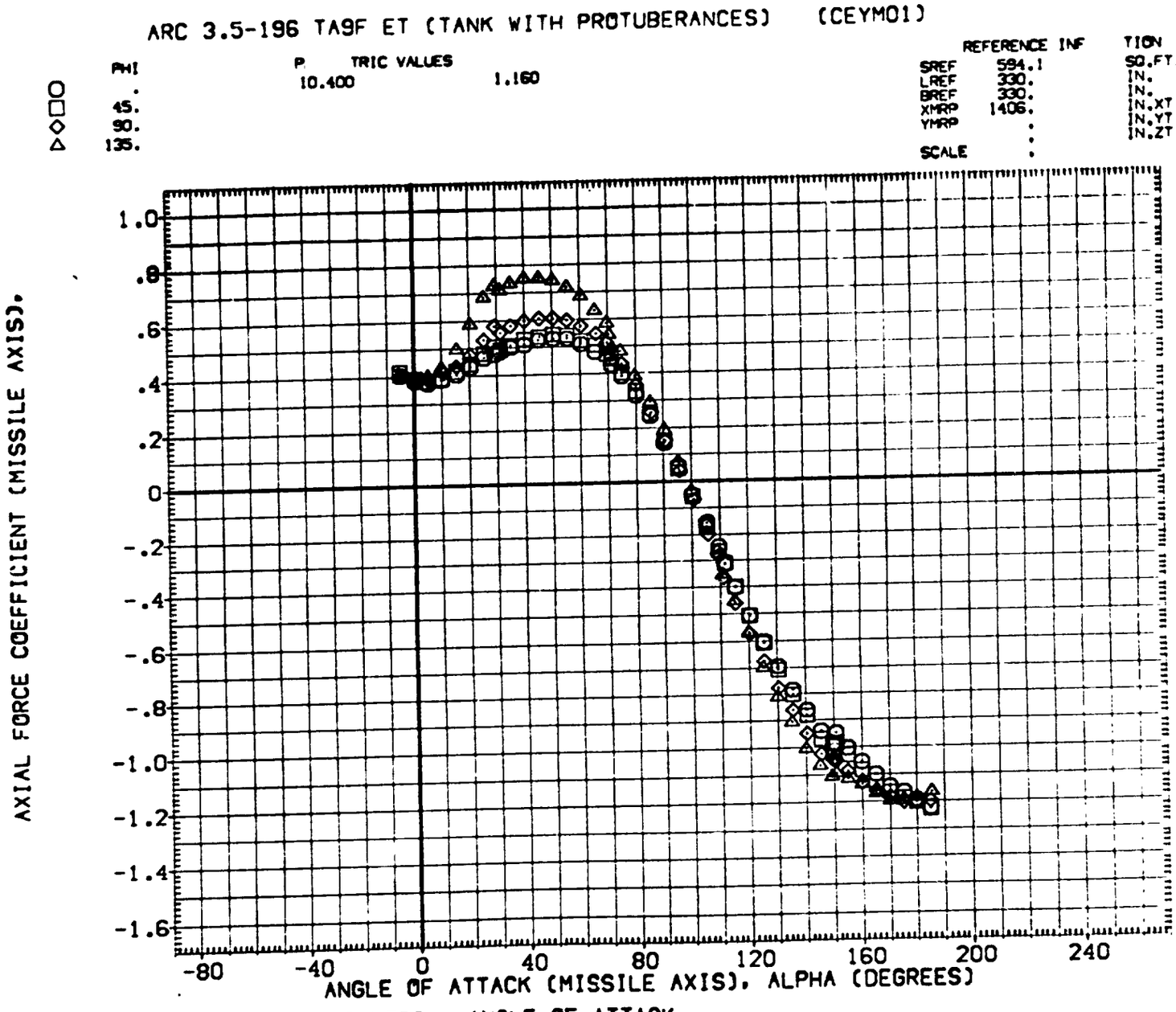


FIG. 4 COEFFICIENTS VERS ANGLE OF ATTACK

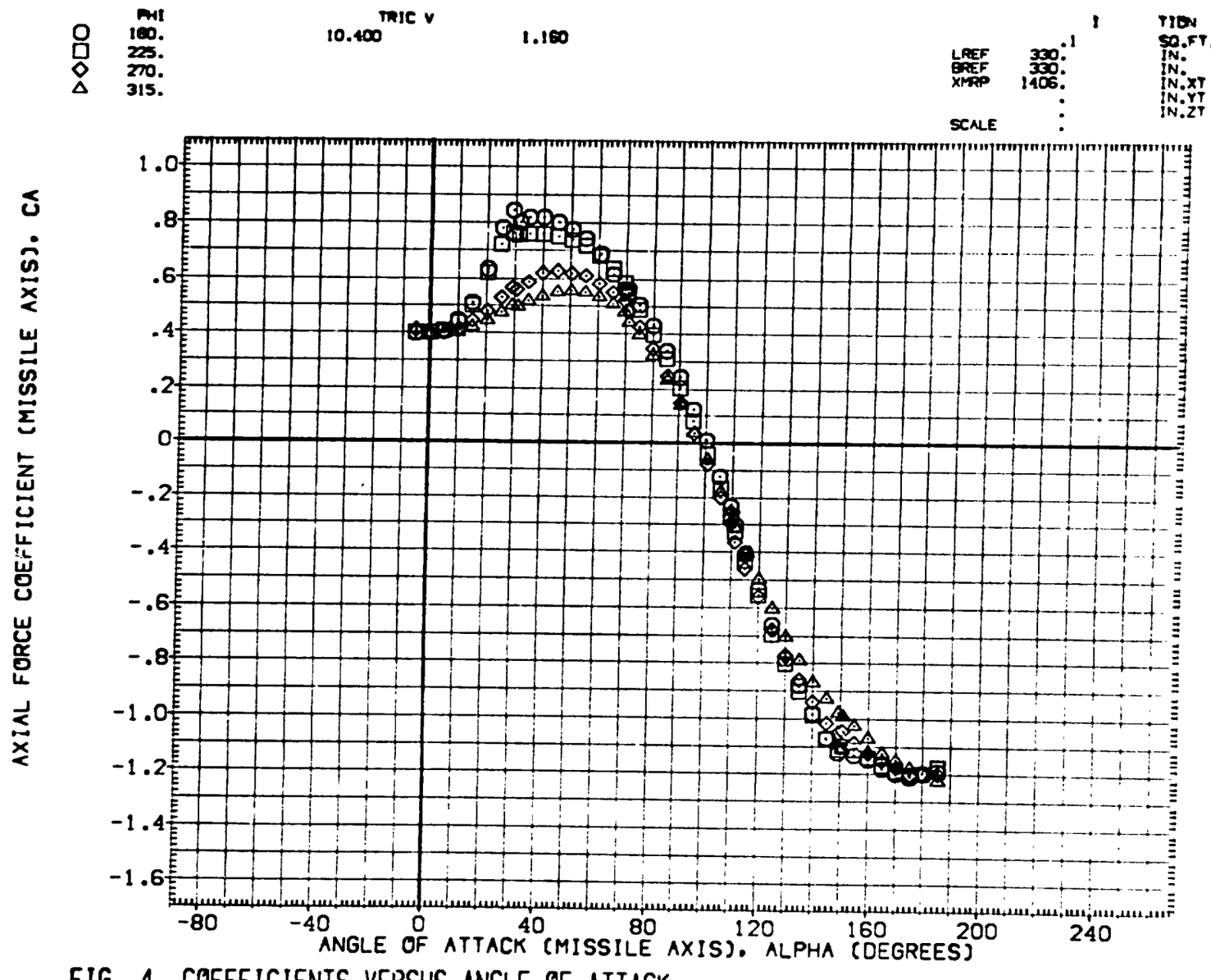


FIG. 4 COEFFICIENTS VERSUS ANGLE OF ATTACK

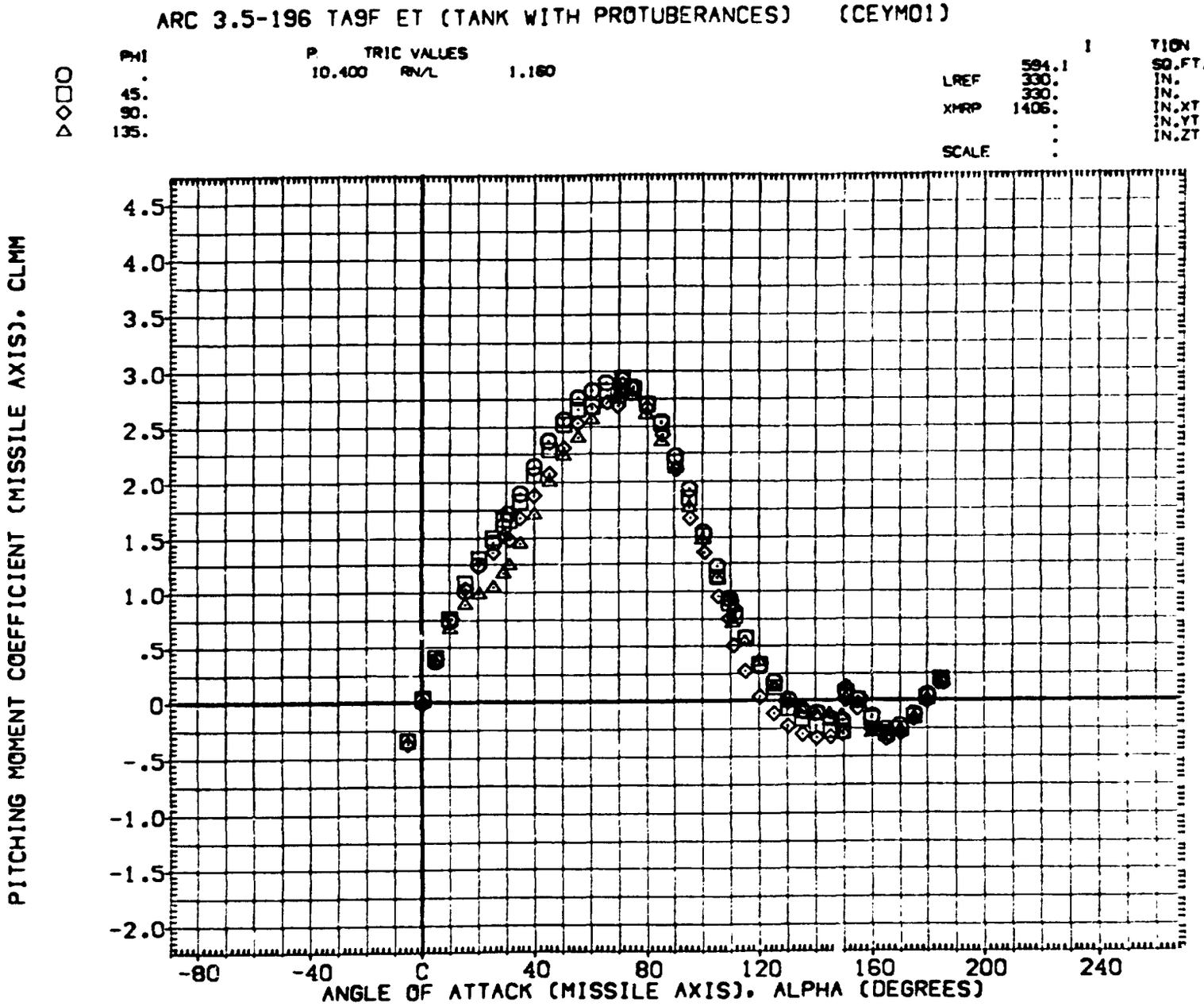
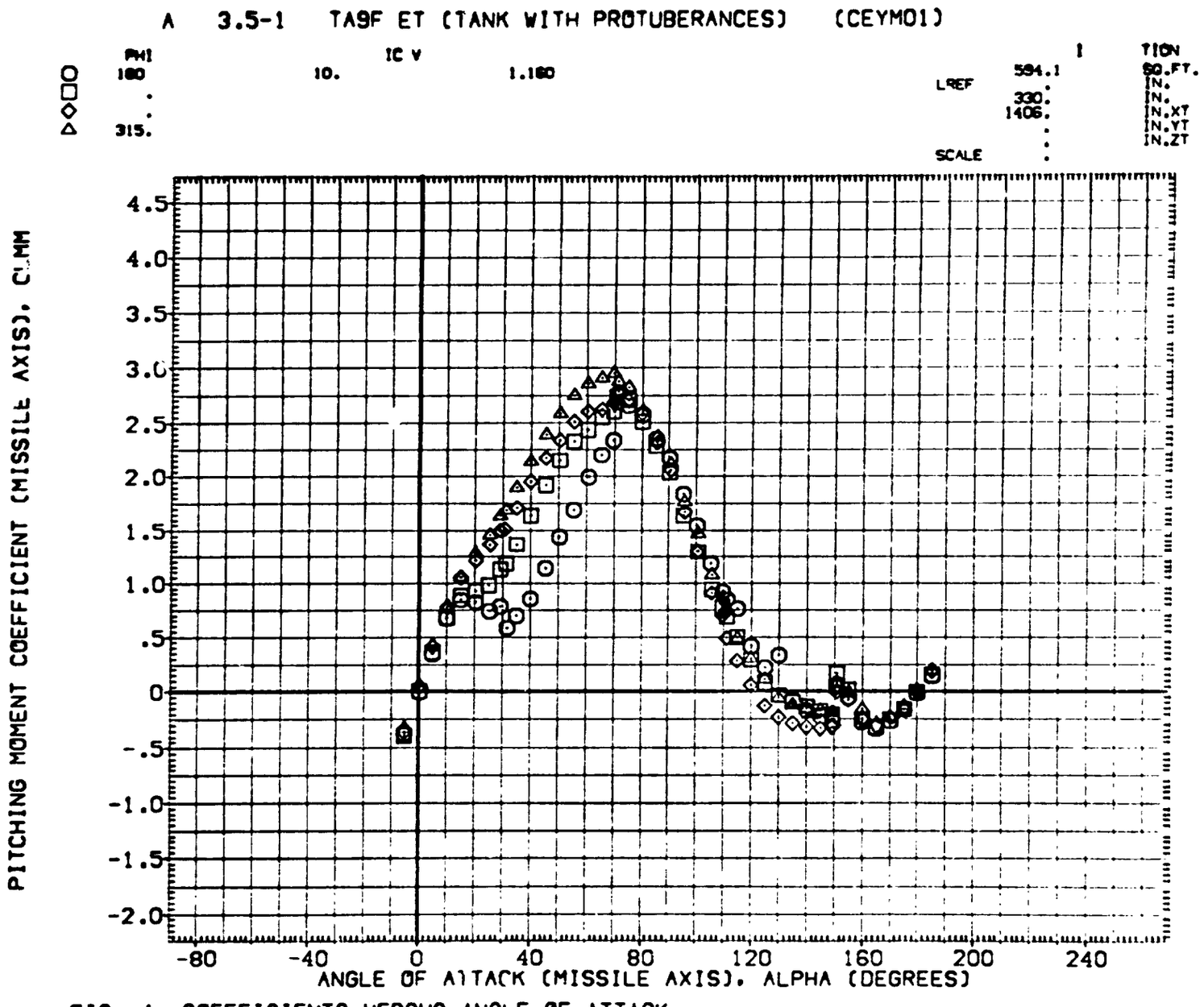


FIG. 4 COEFFICIENTS VERSUS ANGLE OF ATTACK



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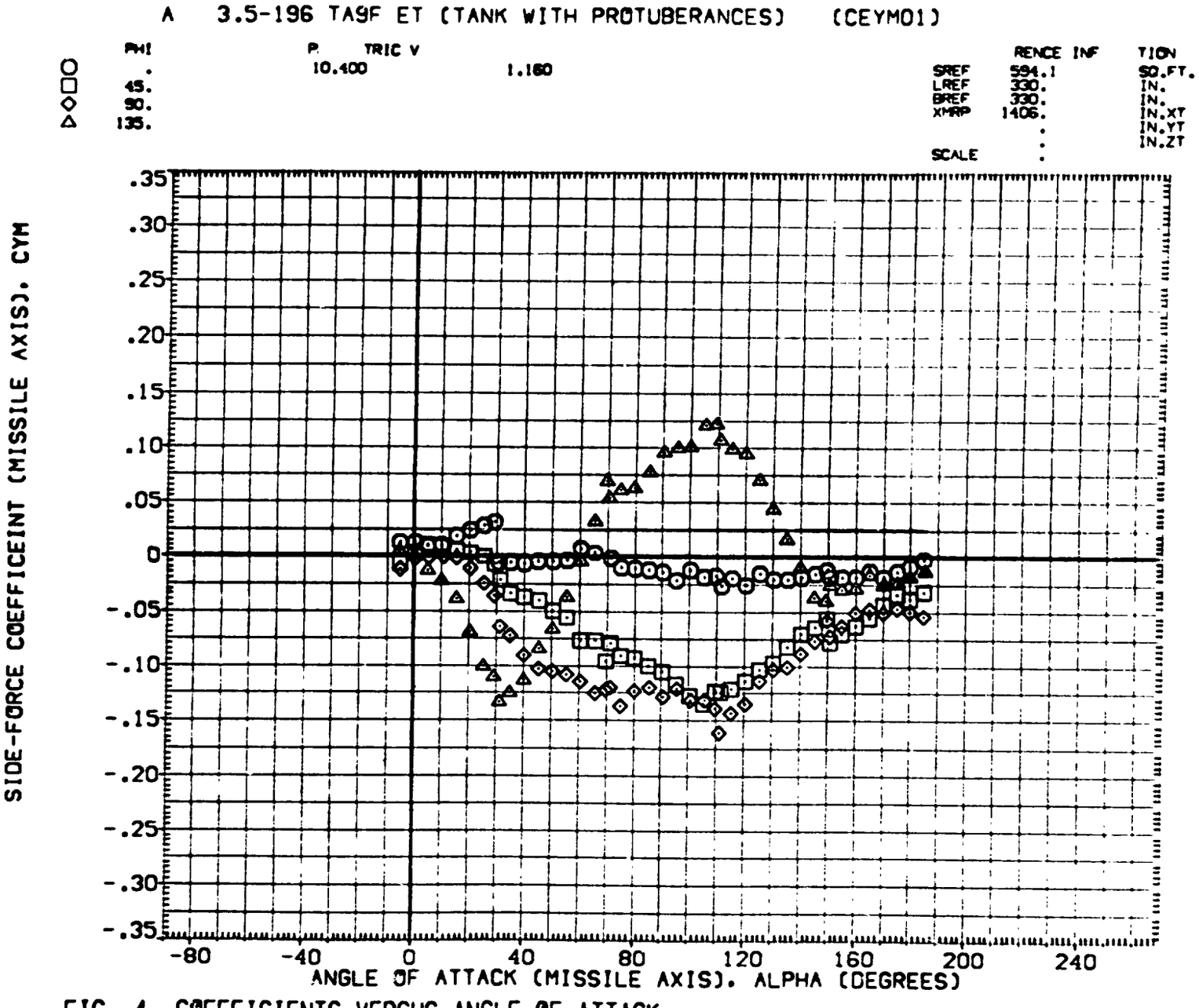

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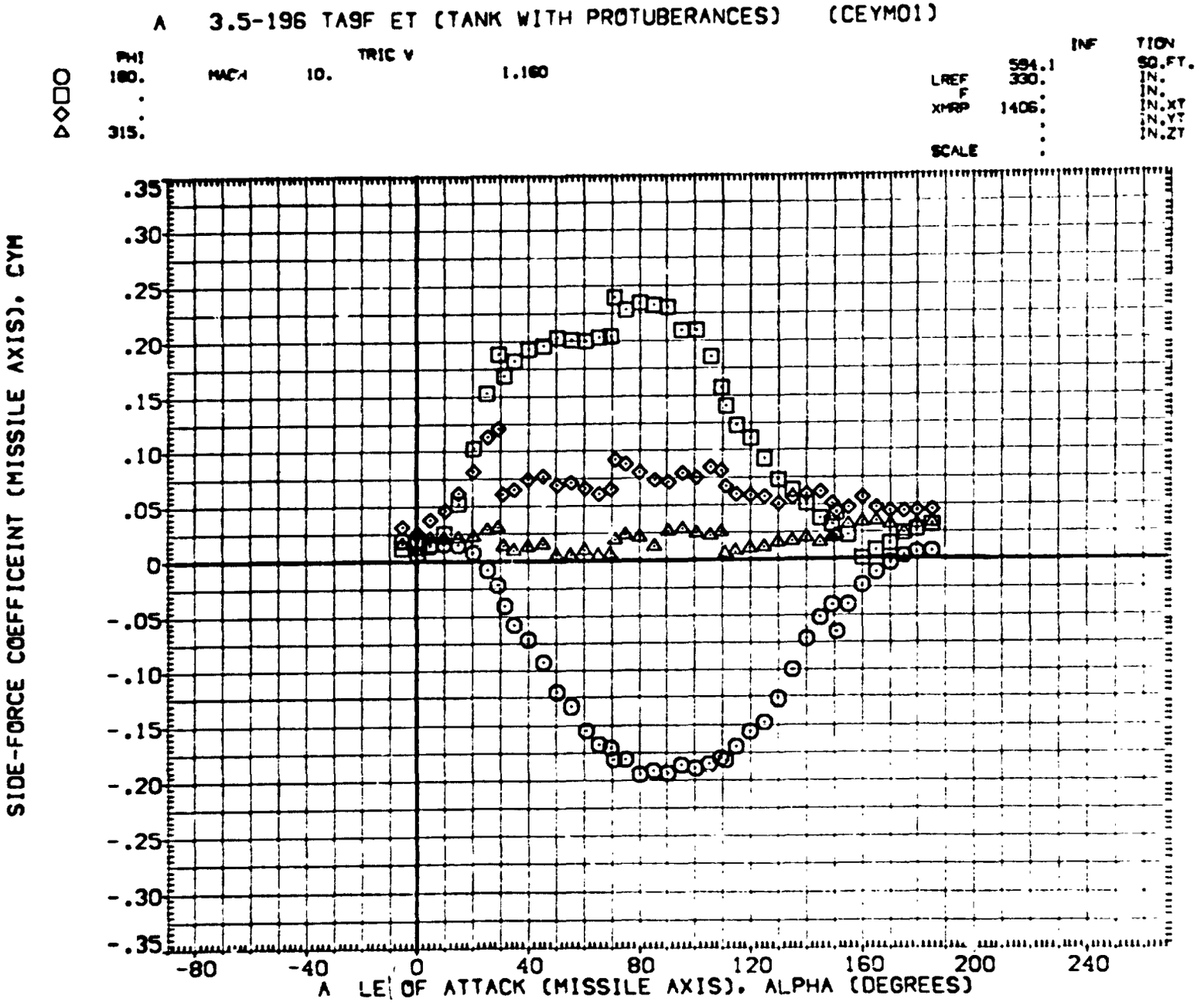
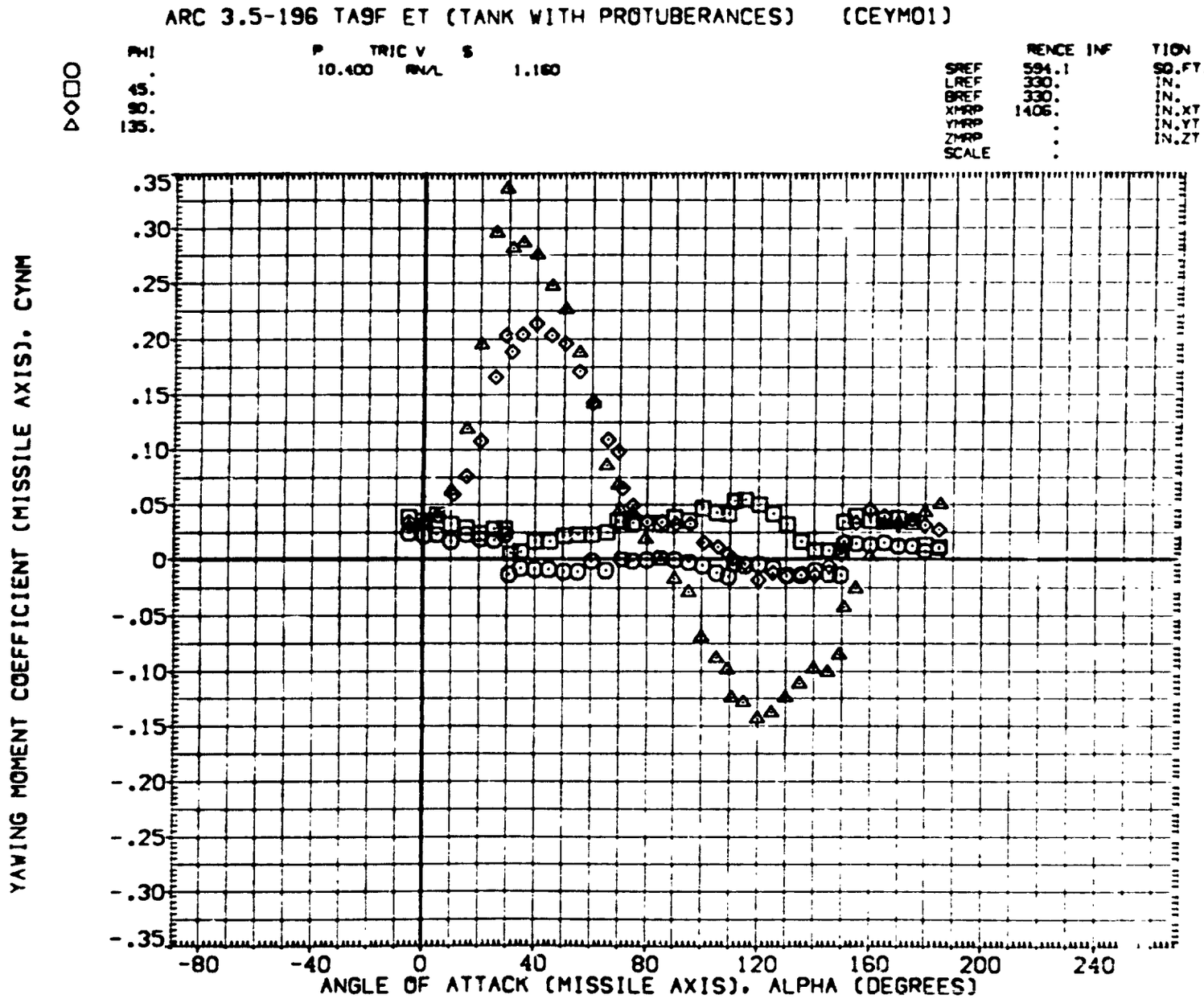


FIG. 4 COEFFICIENTS VE US ANGLE OF ATTACK



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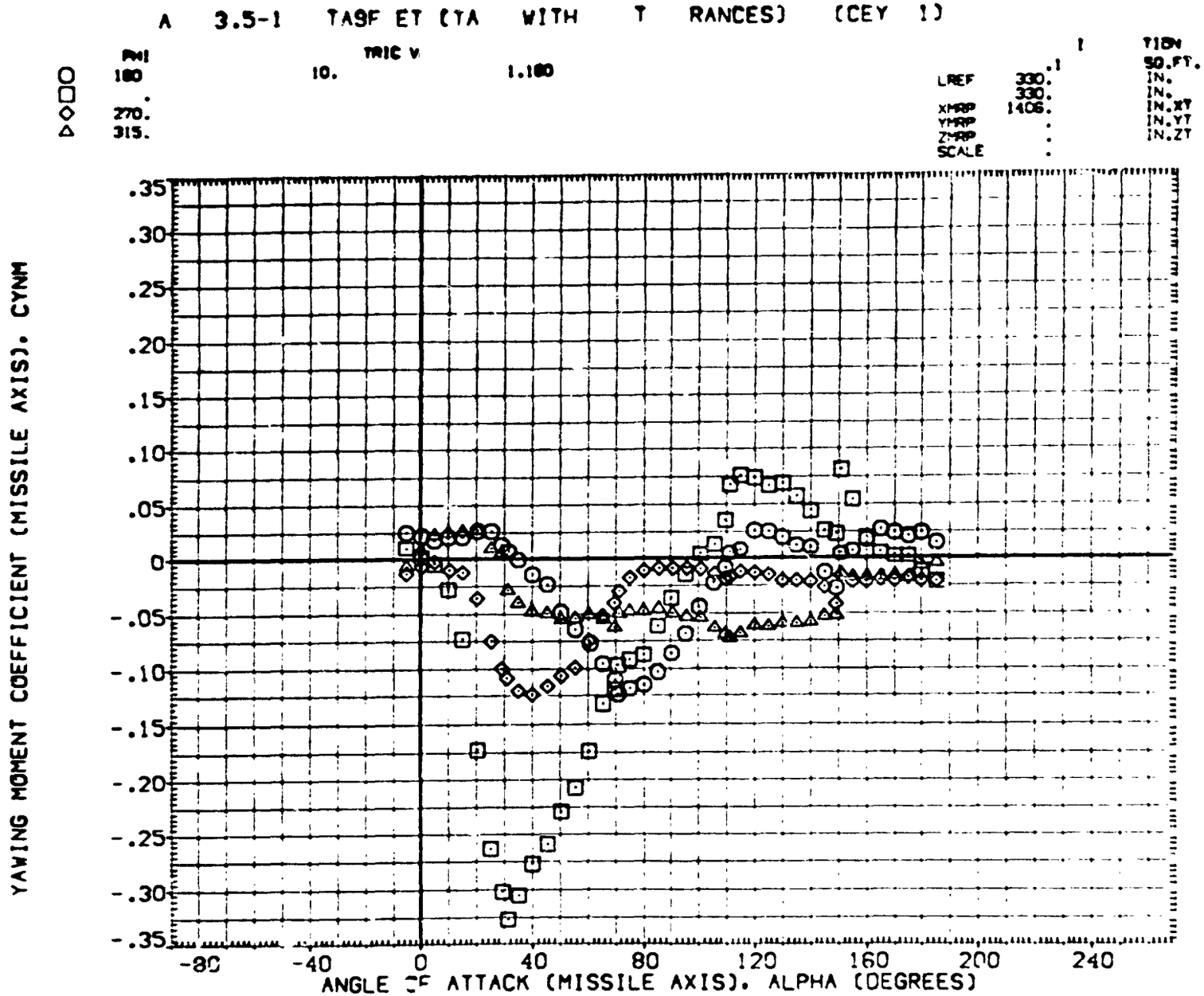

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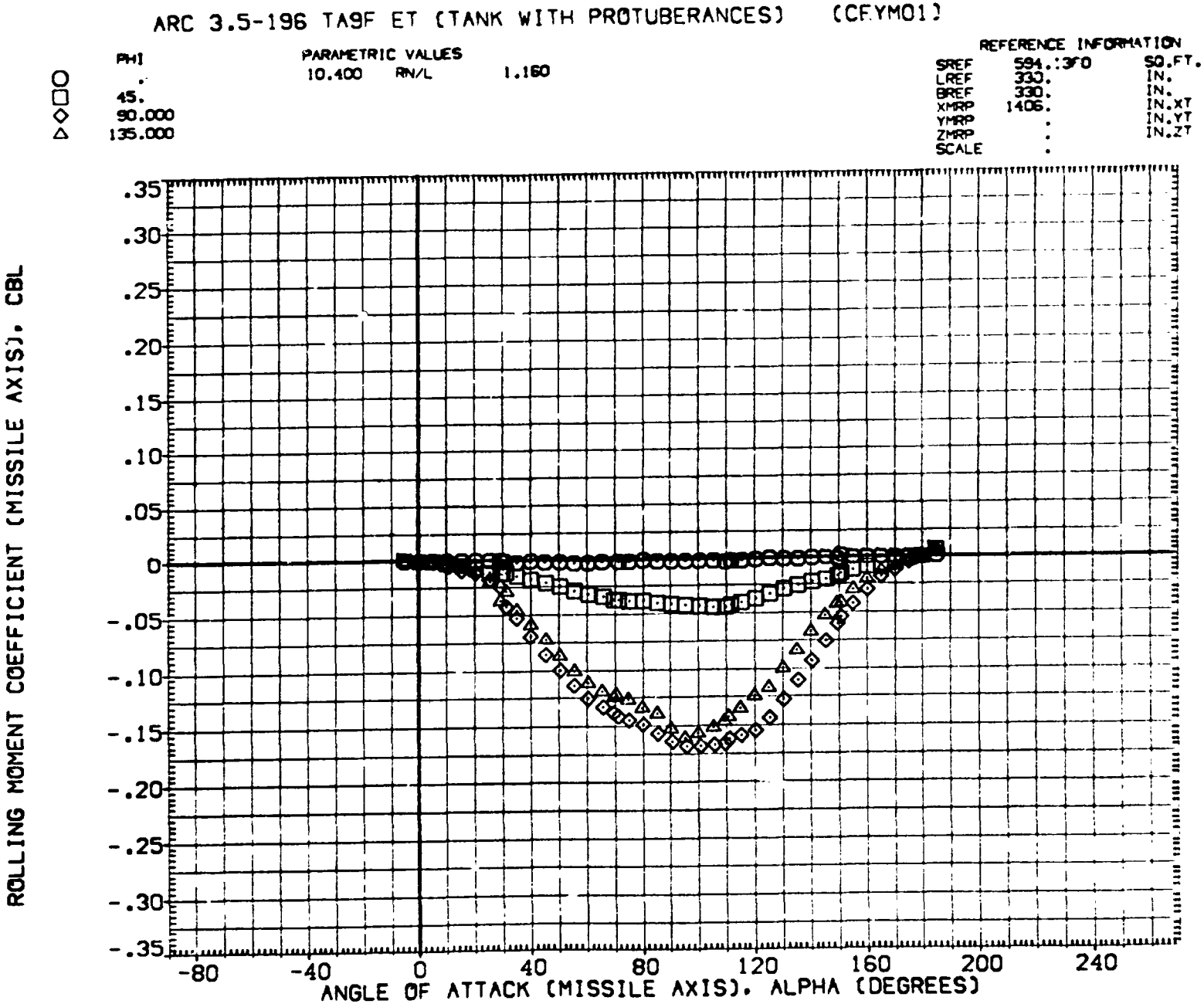

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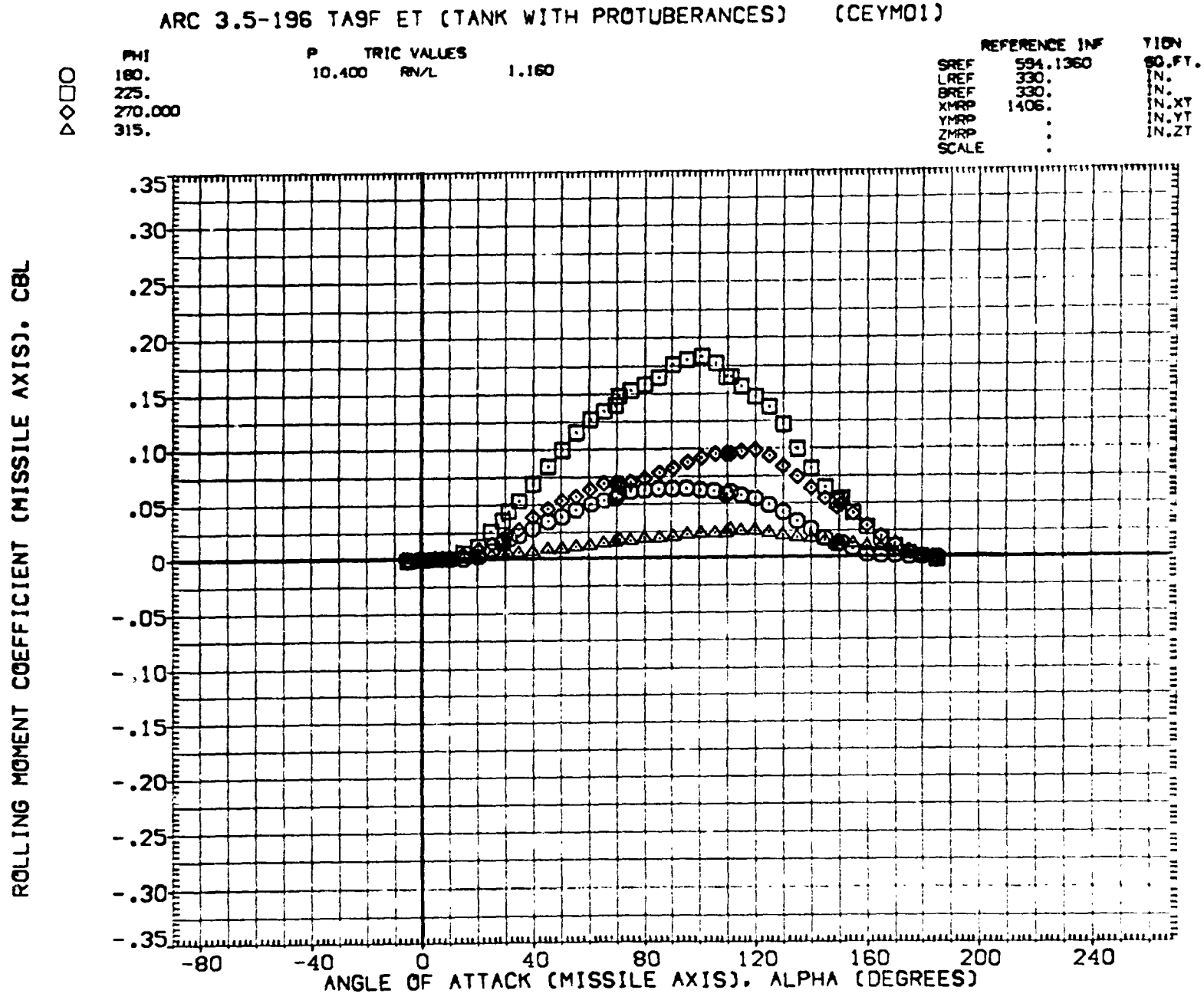

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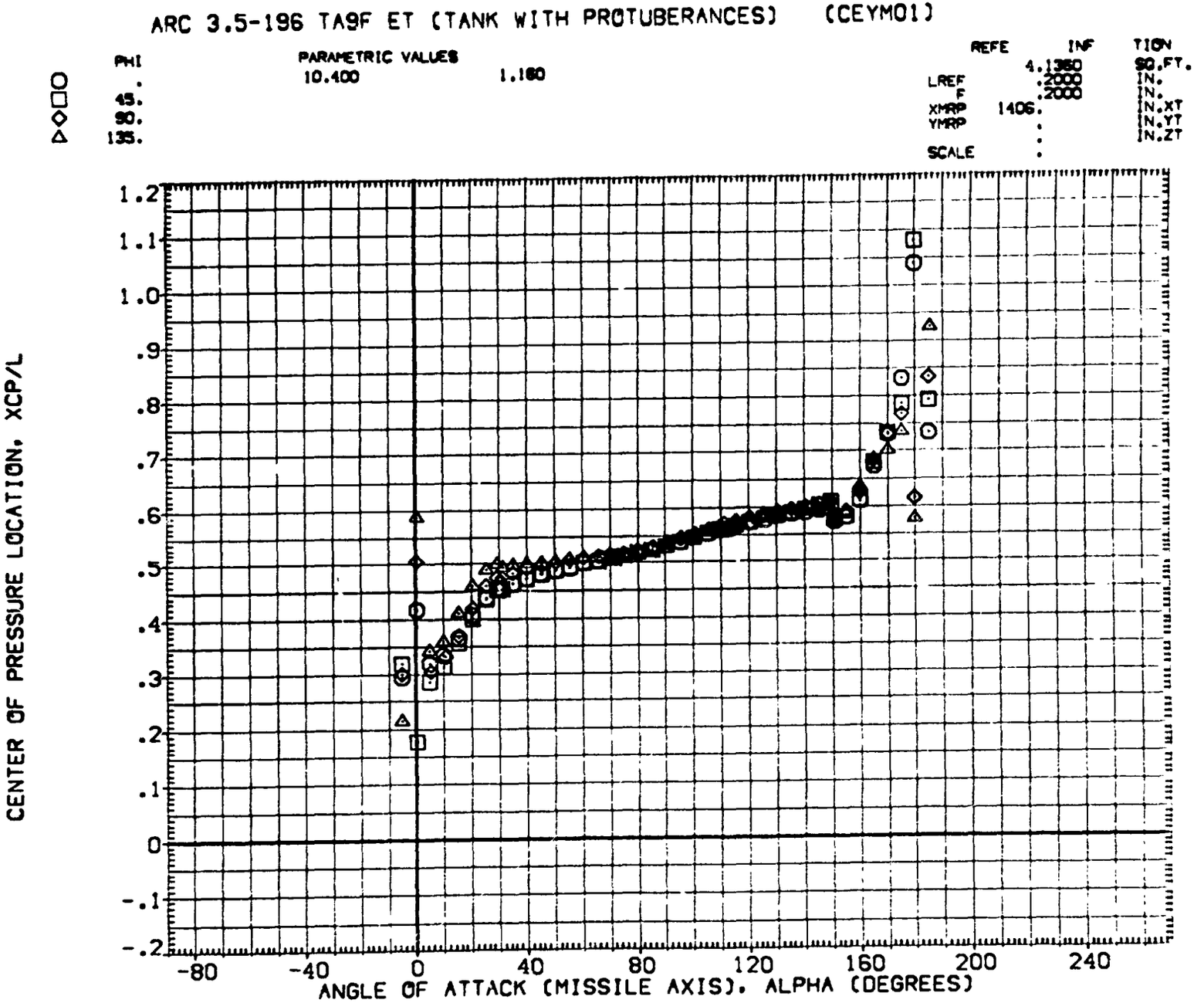

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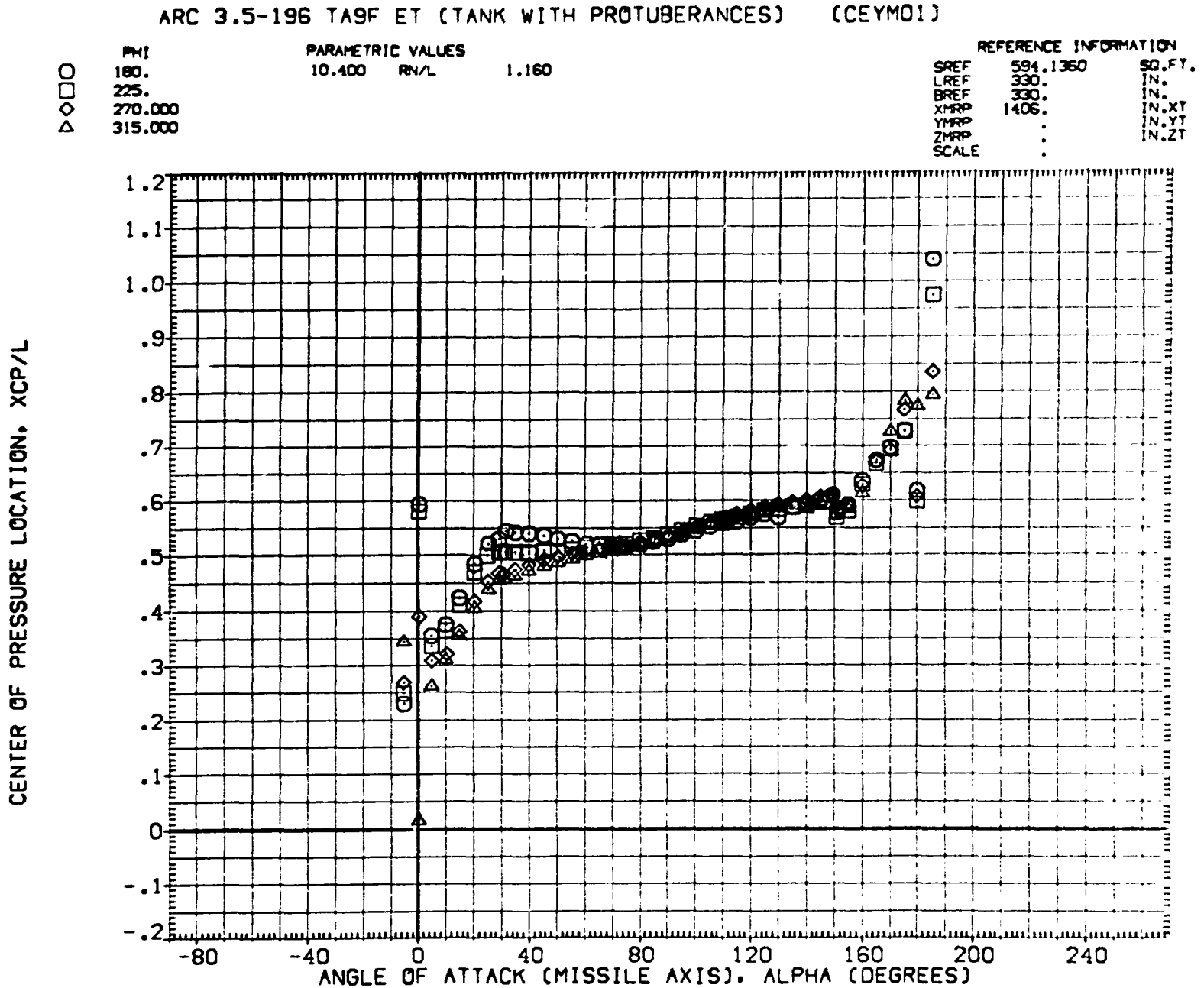

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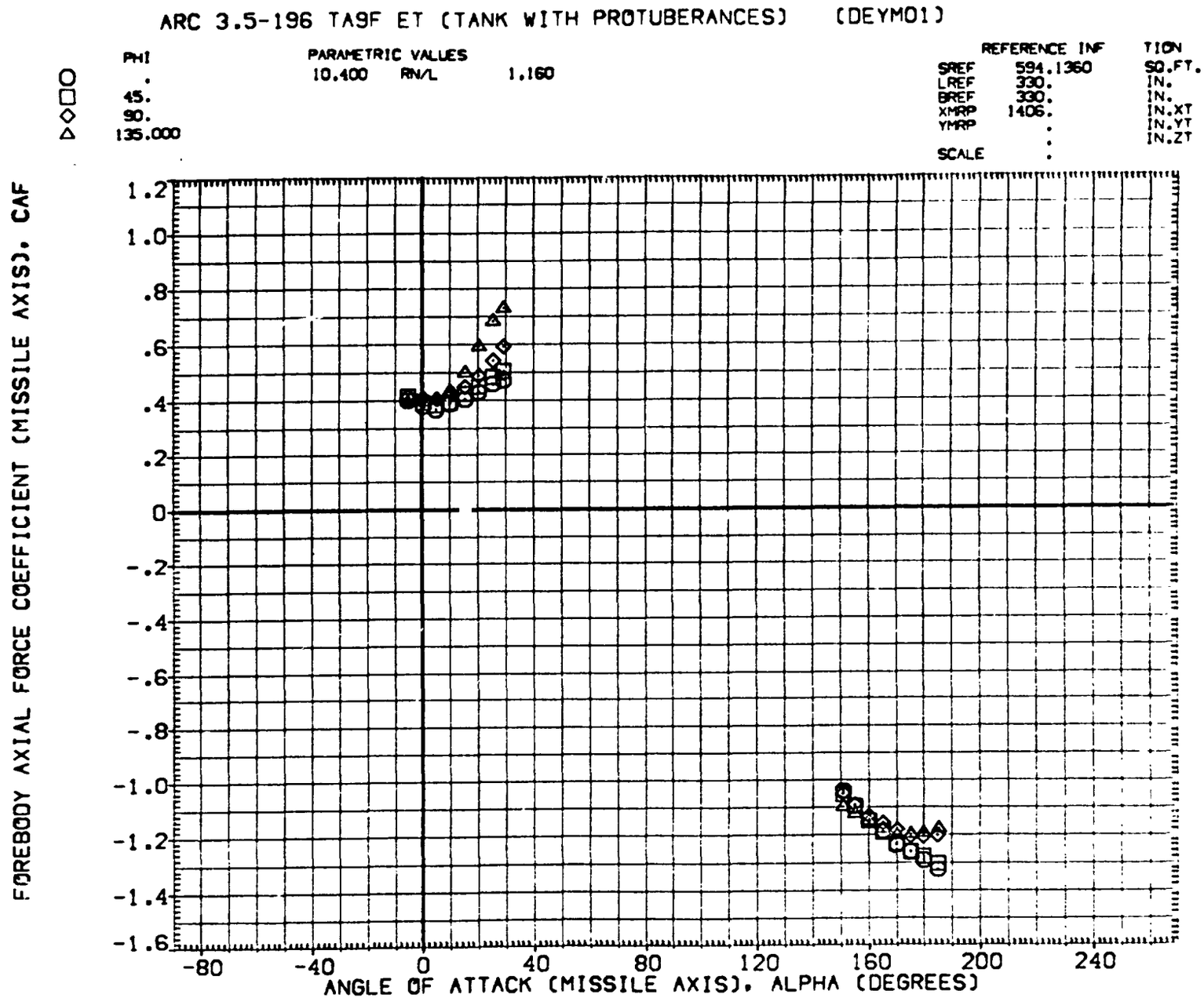

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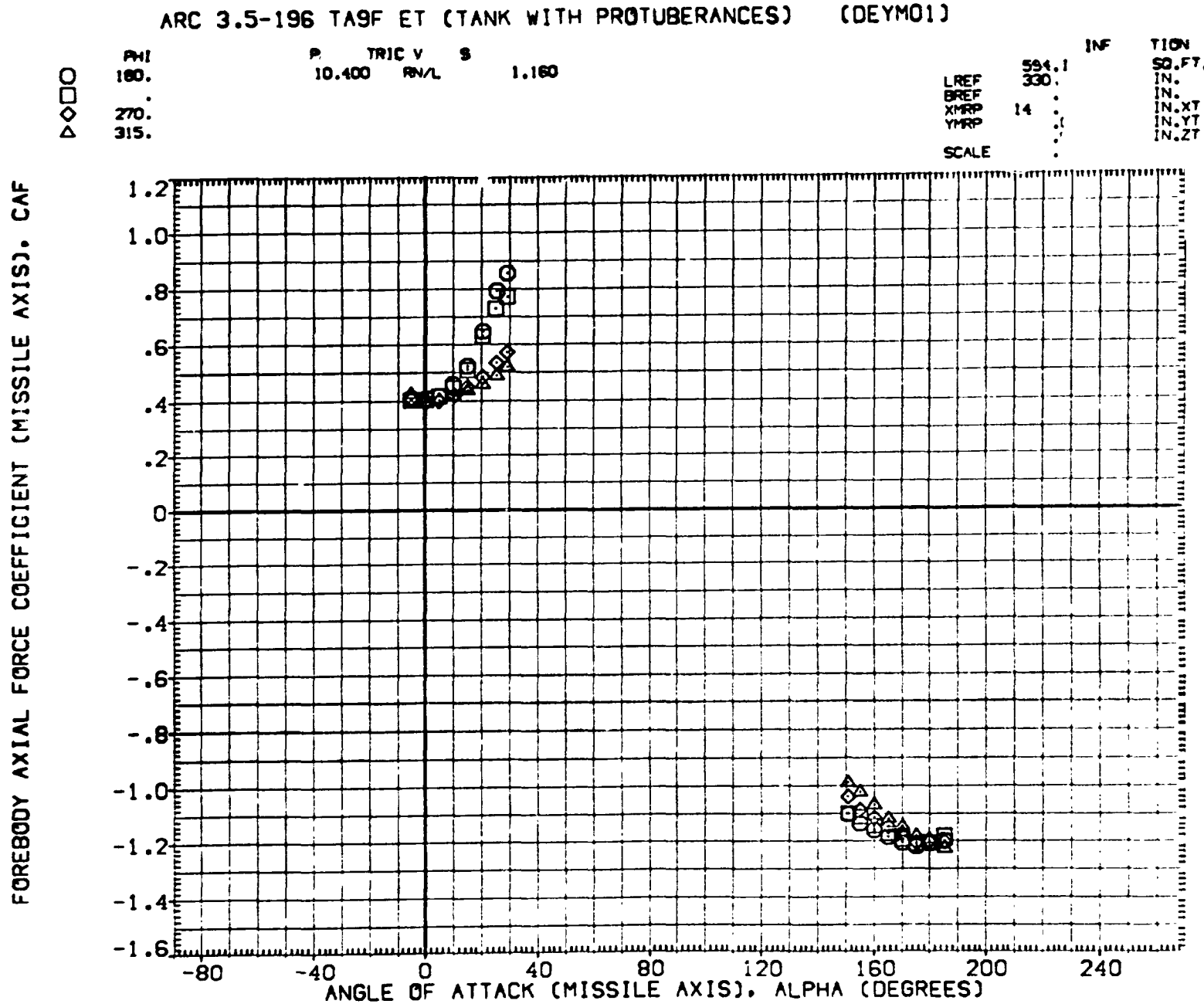
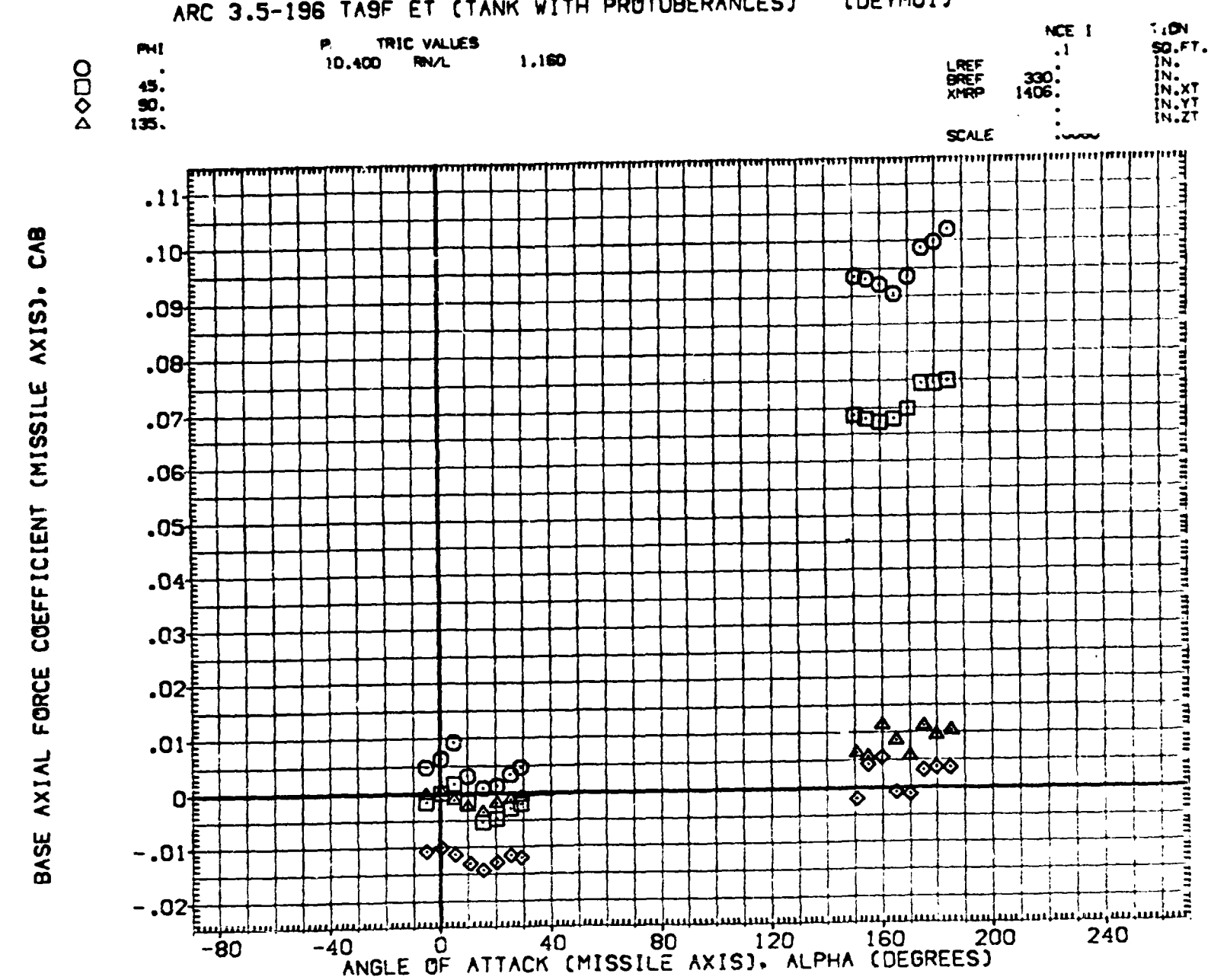


FIG. 4 COEFFICIENTS VERSUS ANGLE OF ATTACK



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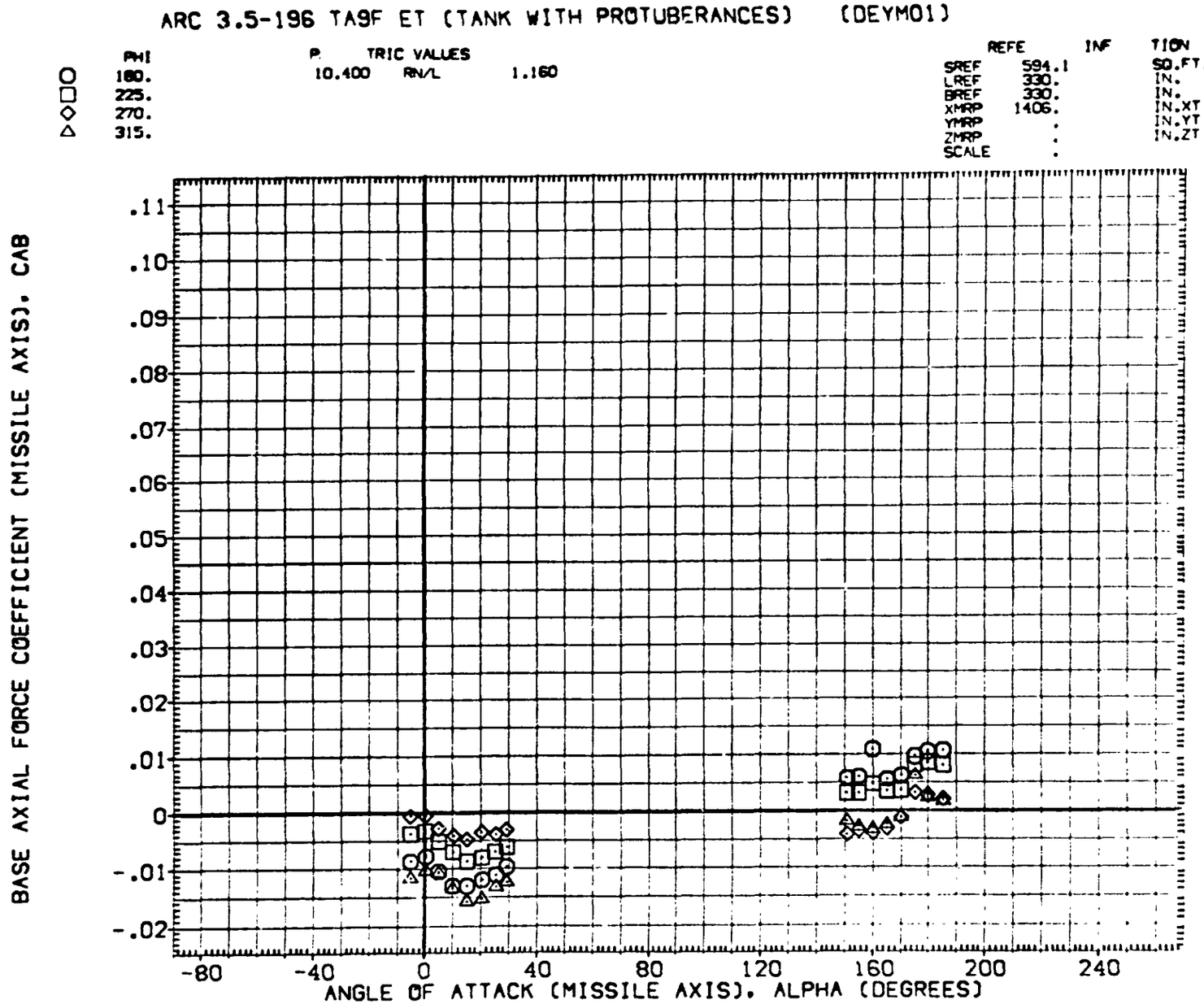

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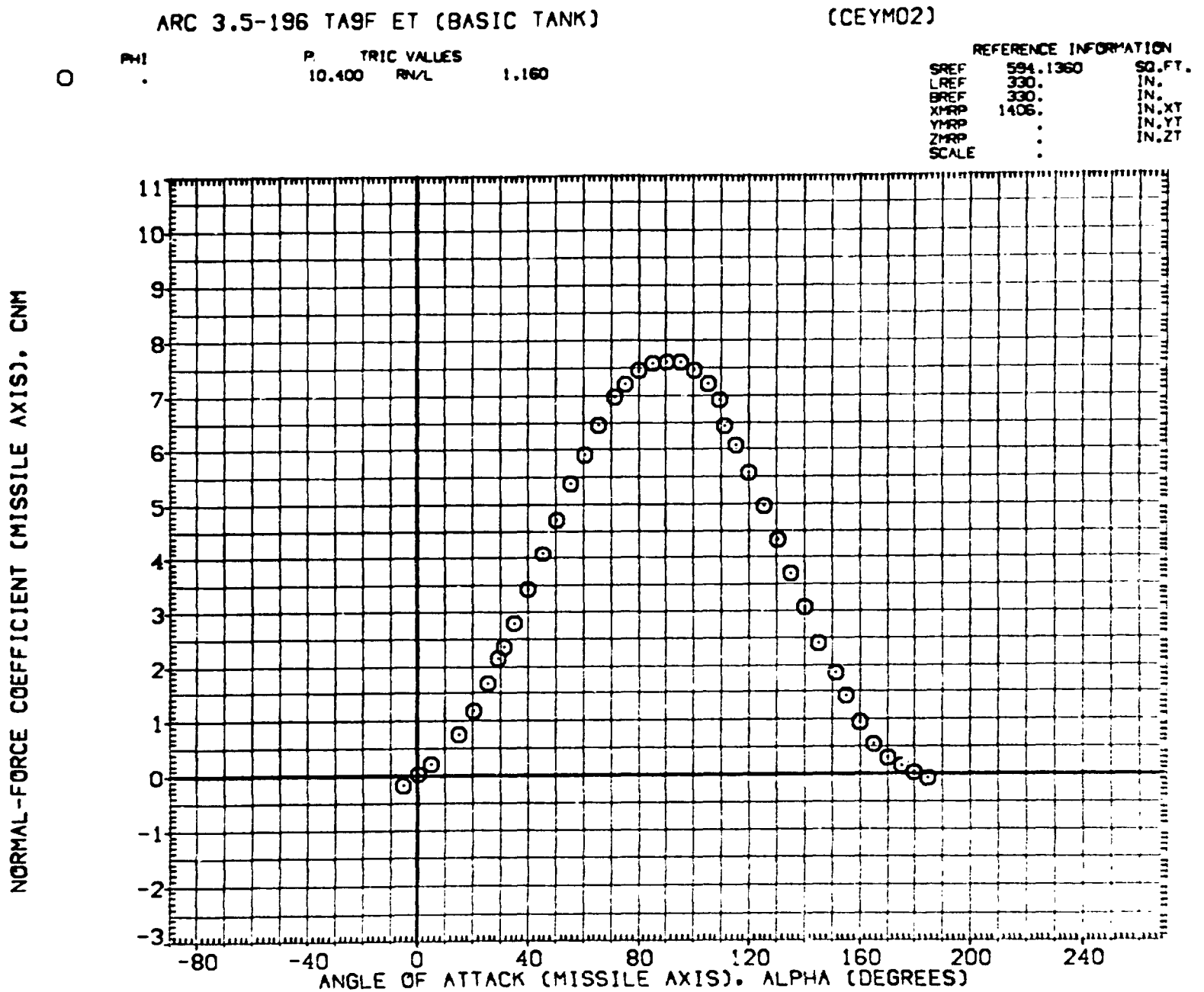

FIG. 5 COEFFICIENTS VERSUS ANGLE OF ATTACK

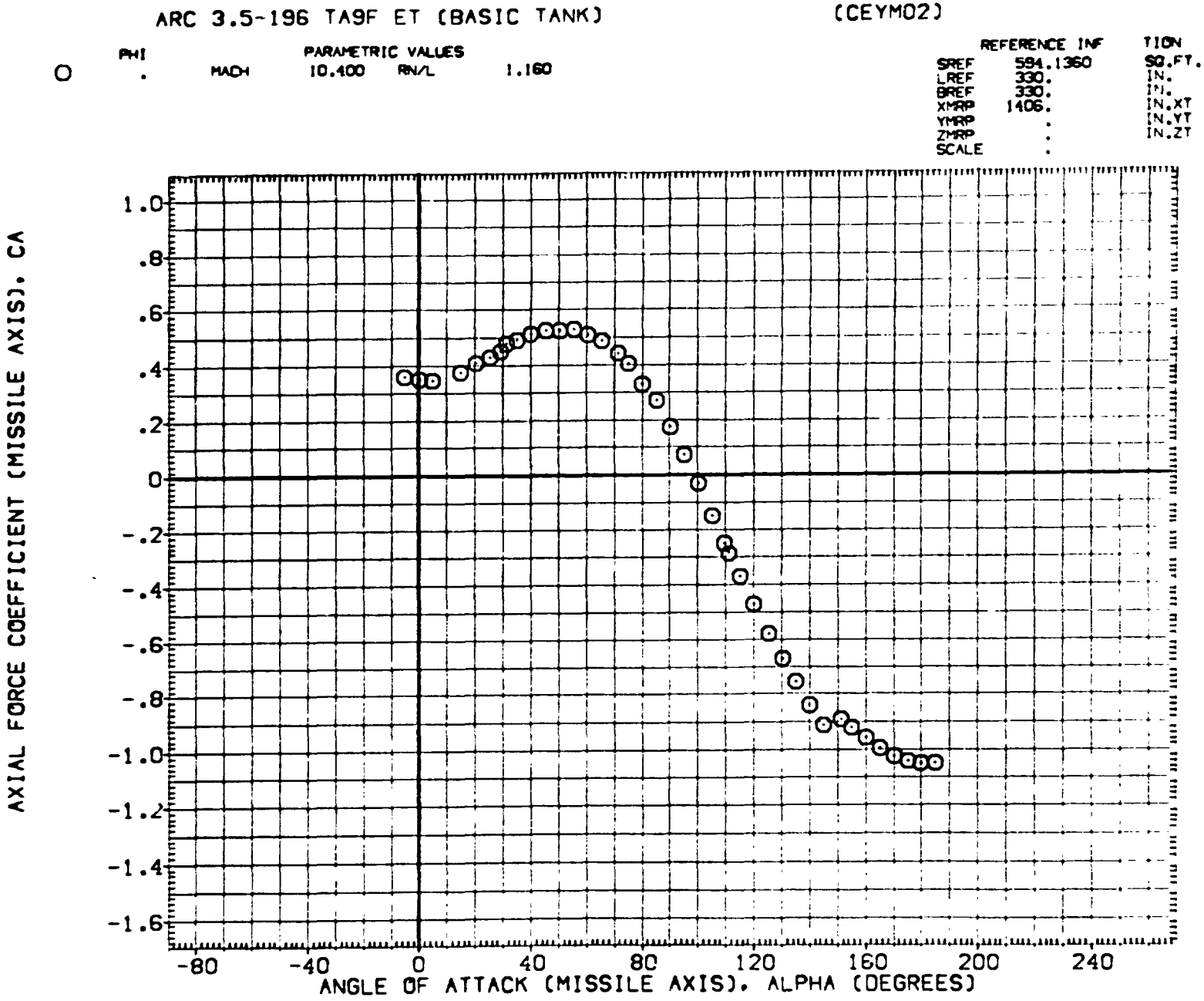

FIG. 5 COEFFICIENTS VERSUS ANGLE OF ATTACK

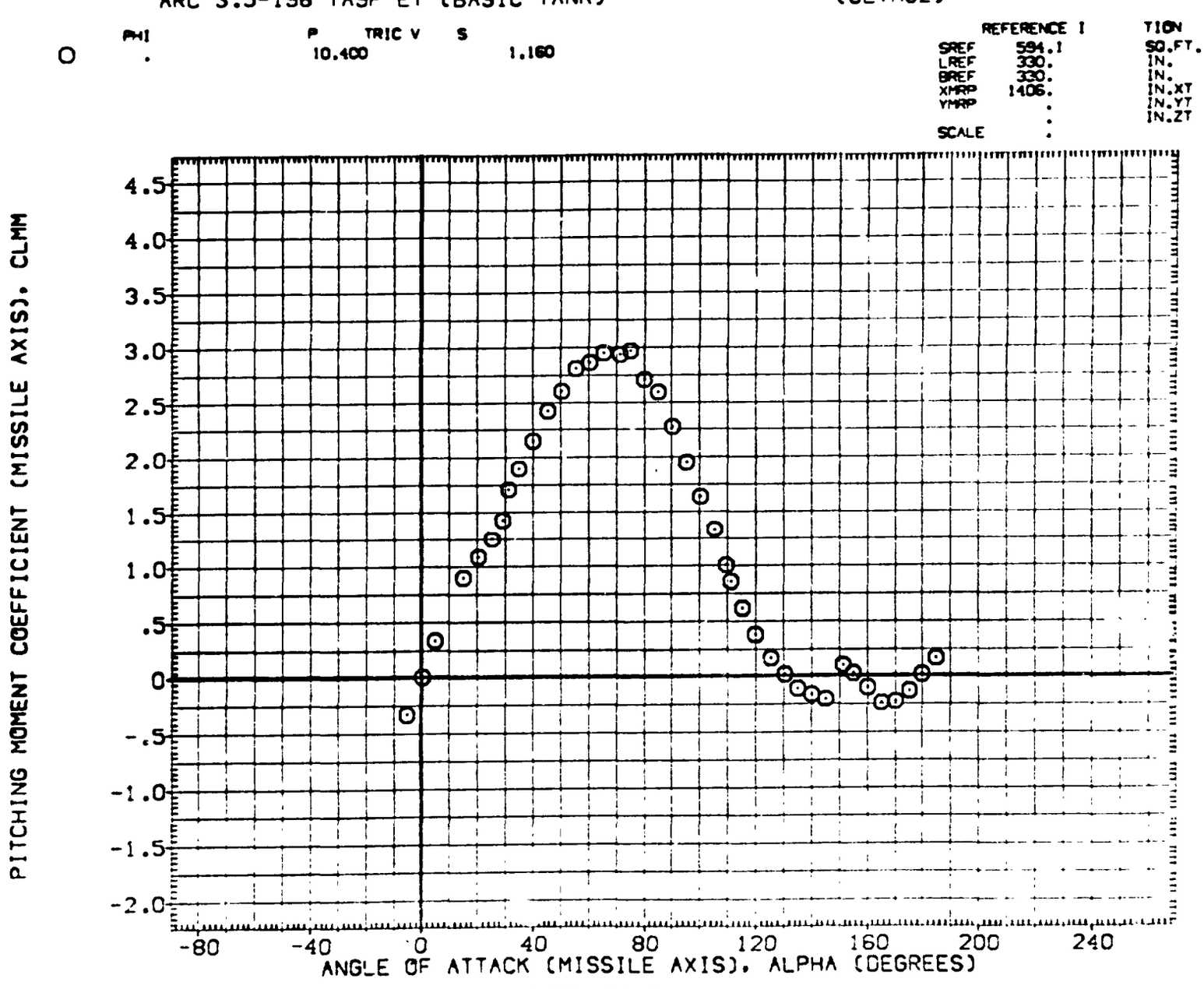

FIG. 5 COEFFICIENTS VERSUS ANGLE OF ATTACK

A 3.5-196 TA9F ET (BASIC TANK) (CEYM02)

	PHI	P TRIC VALUES		
O	.	10.400	RN/L	1.160

REFERENCE INFORMATION

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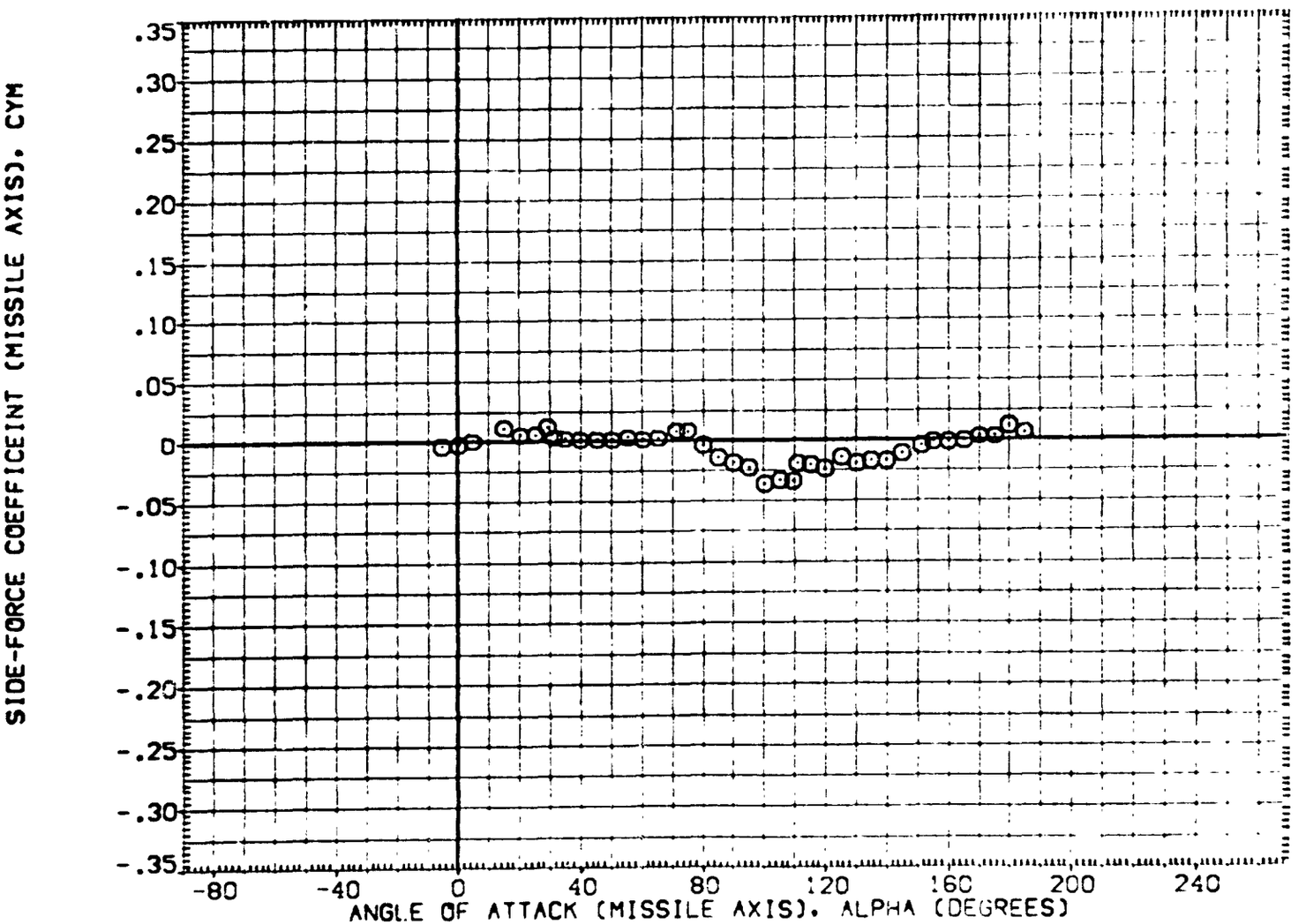

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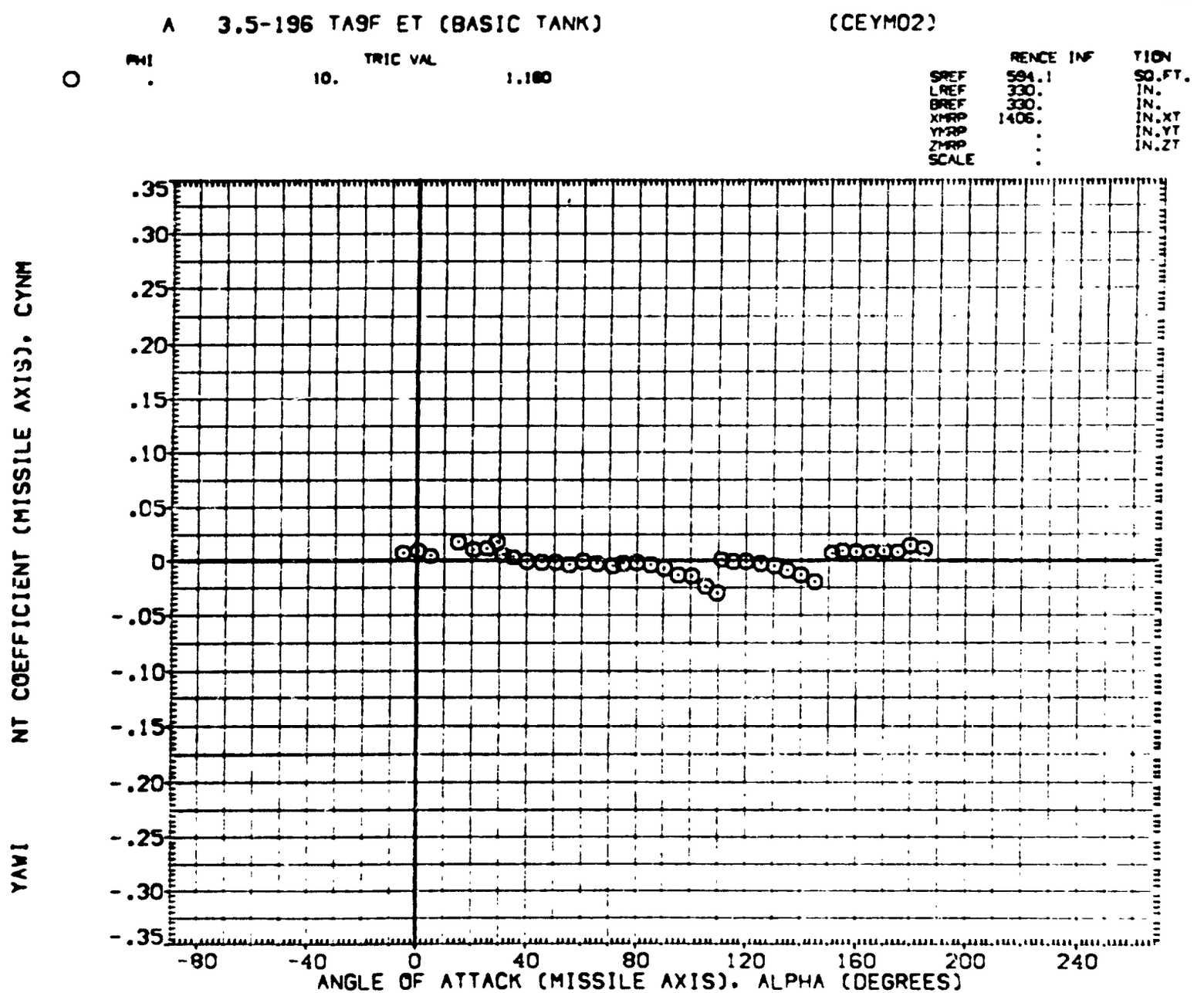

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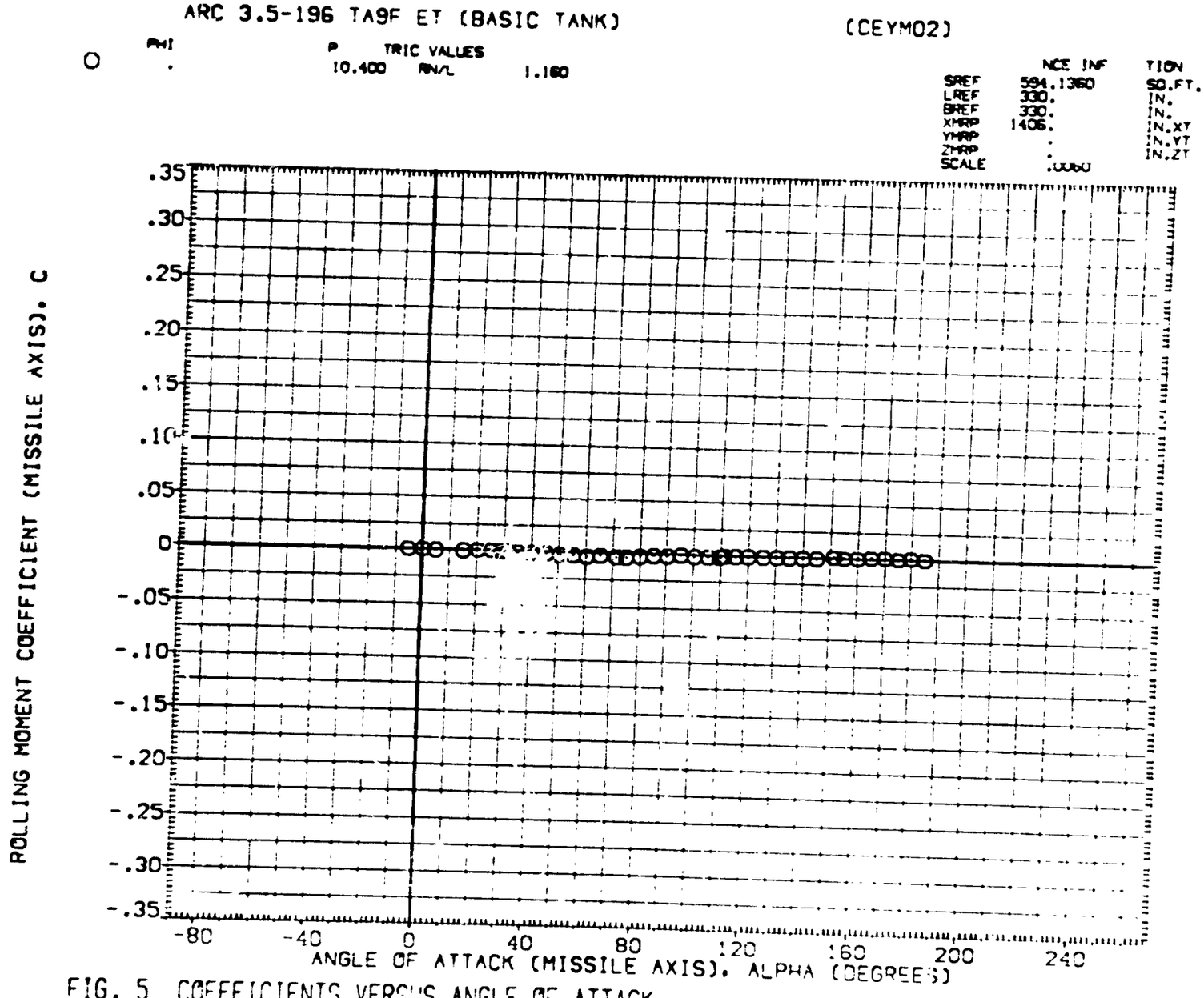


FIG. 5 COEFFICIENTS VERSUS ANGLE OF ATTACK

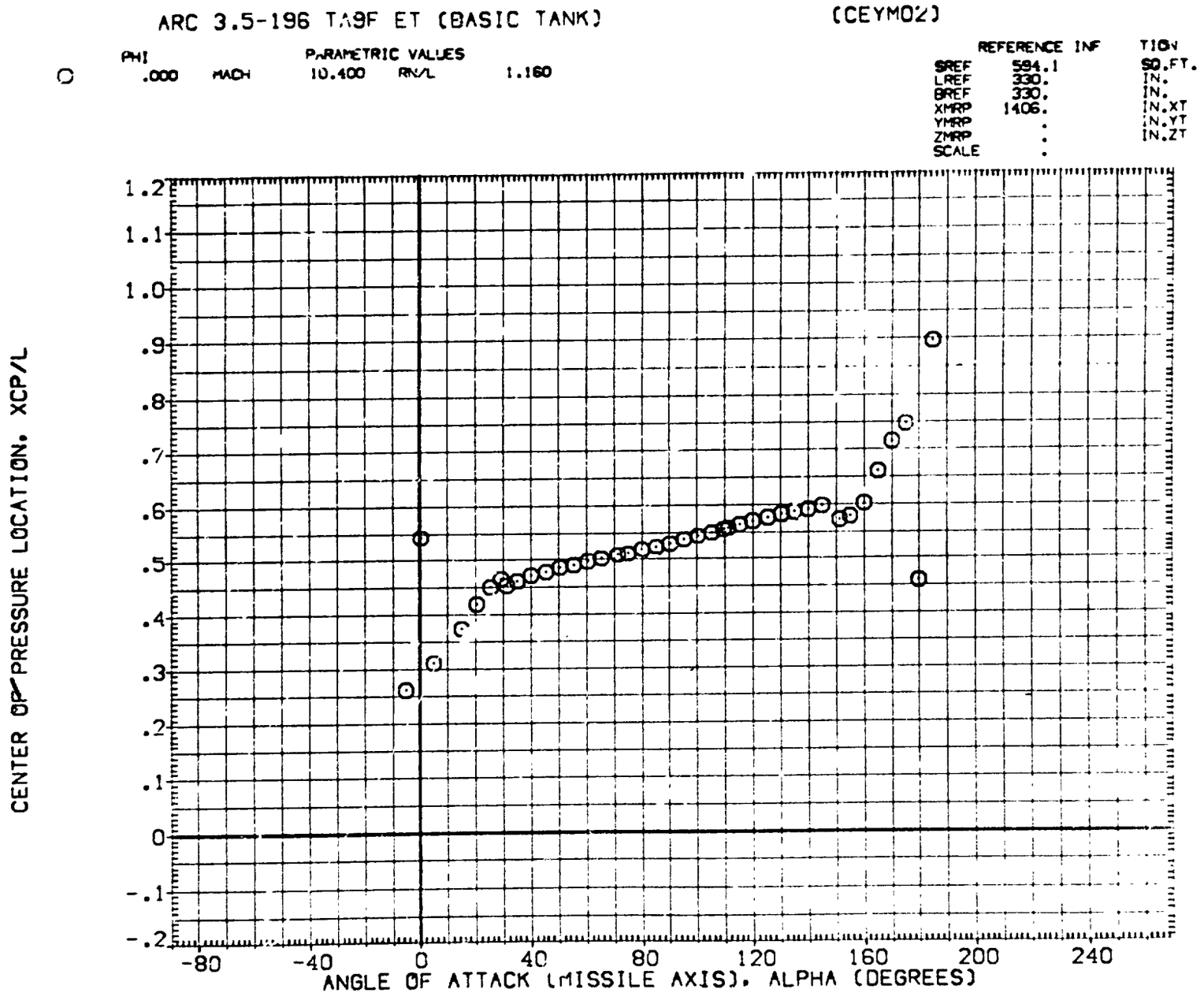
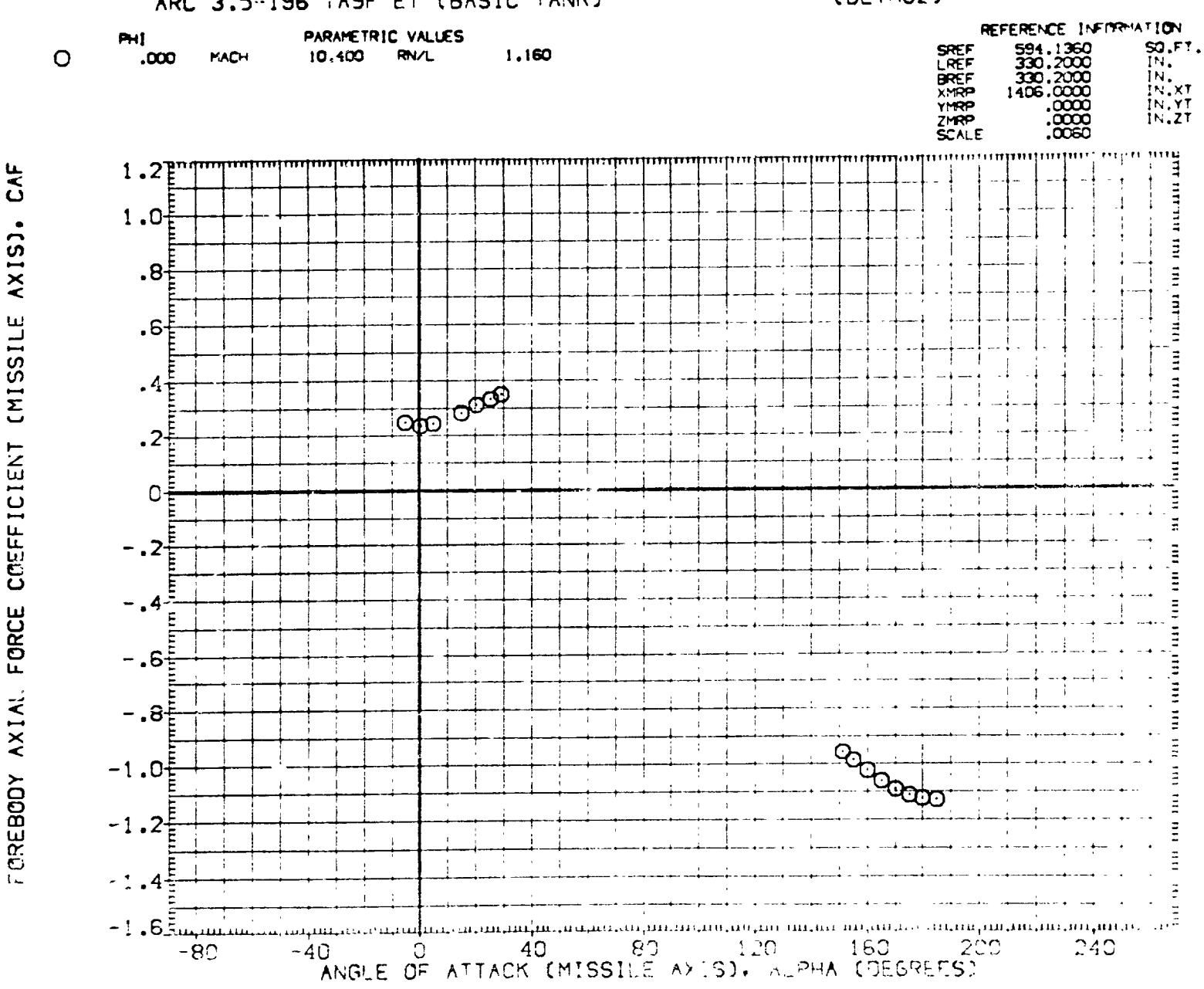


FIG. 5 COEFFICIENTS VERSUS ANGLE OF ATTACK



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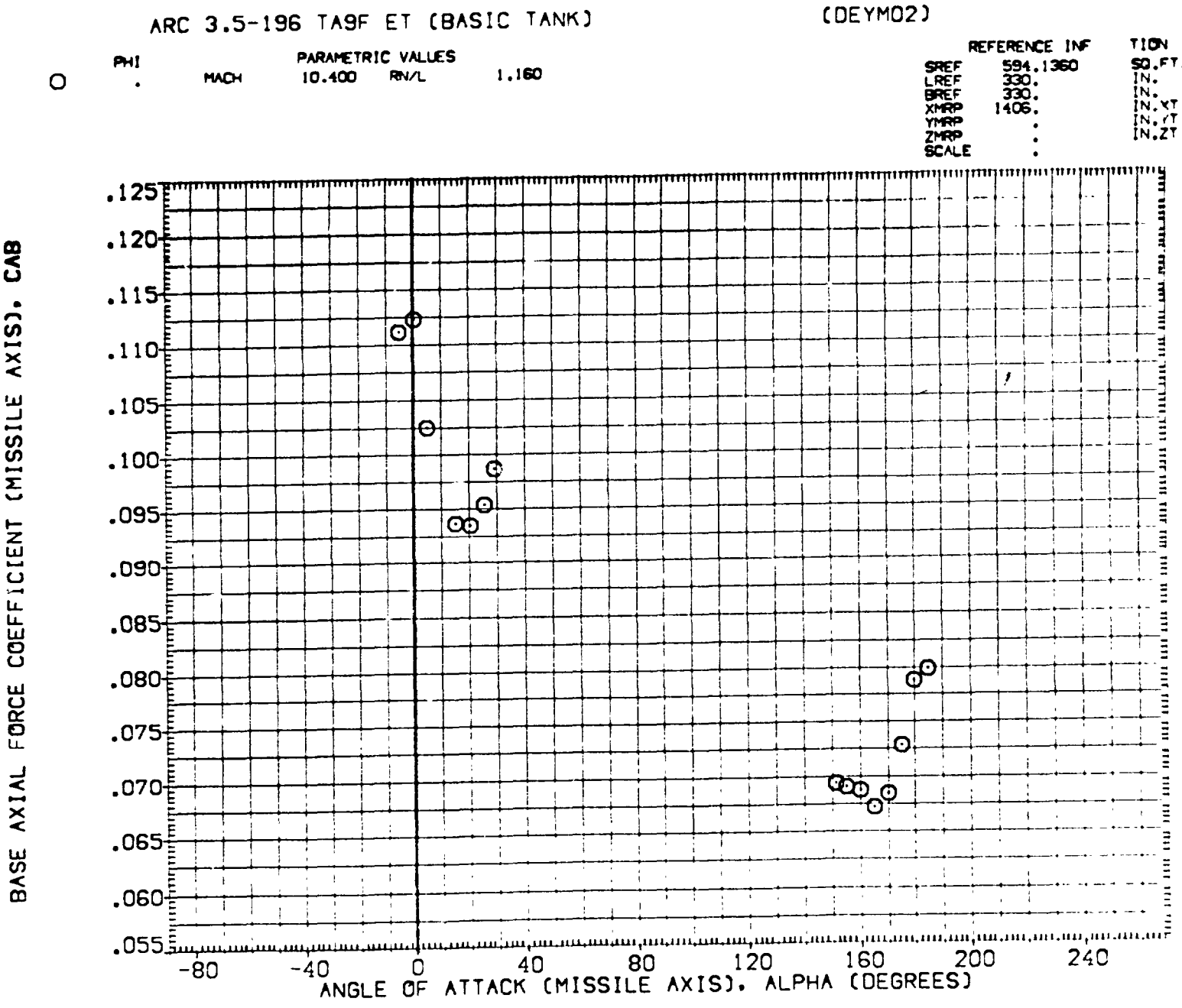


FIG. 5 COEFFICIENTS VERSUS ANGLE OF ATTACK

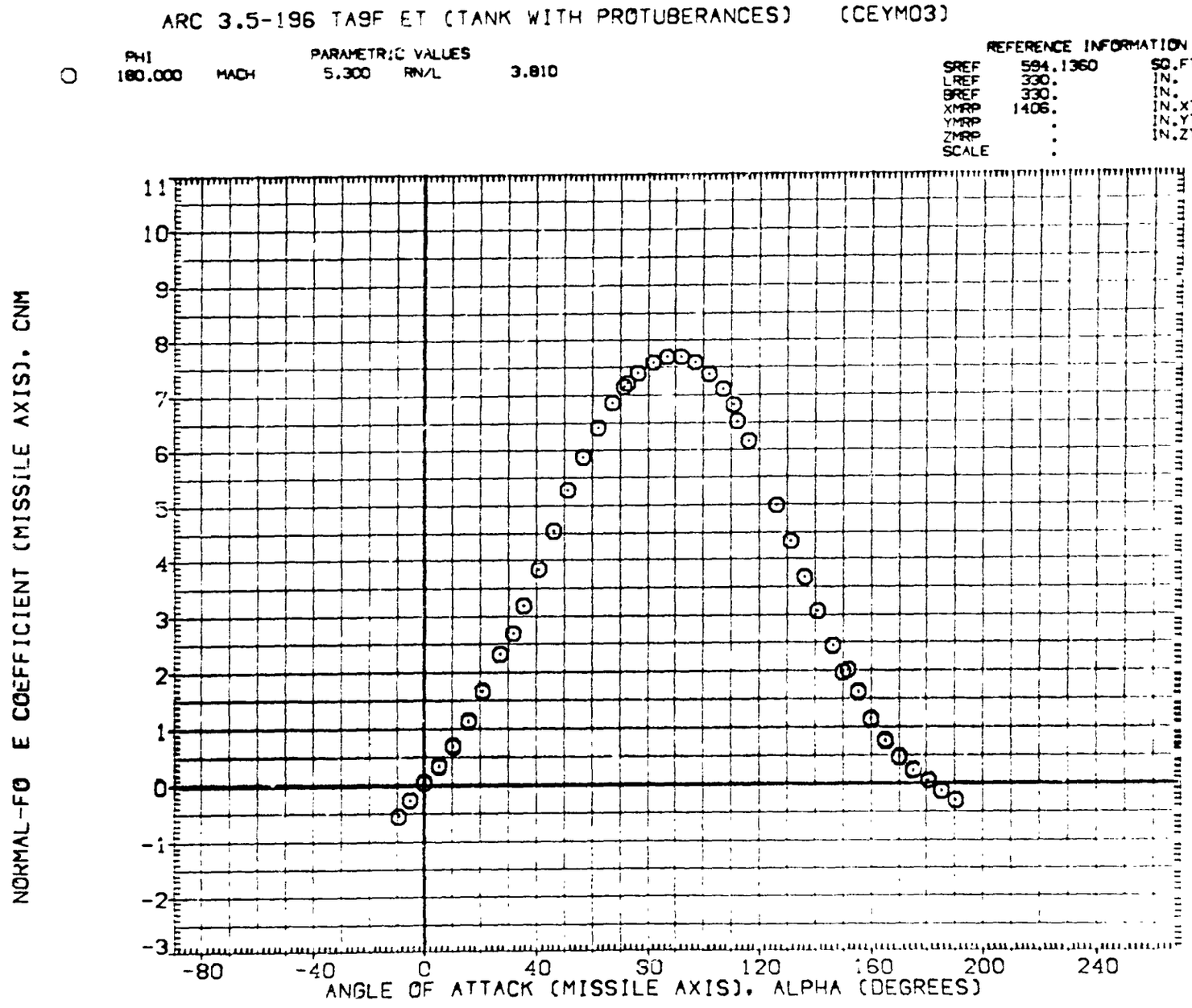
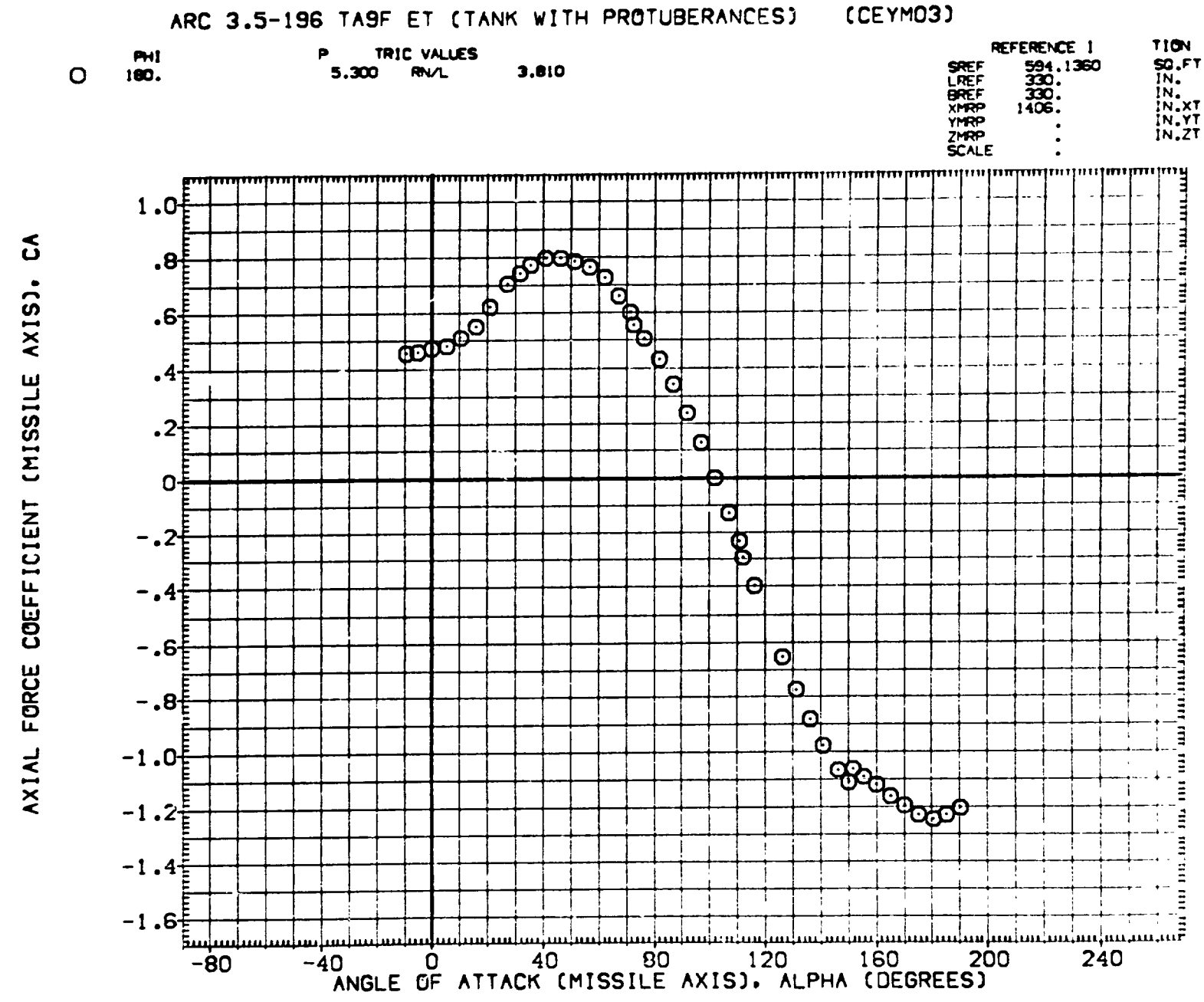


FIG. 6 COEFFICIENTS VERSUS ANGLE OF ATTACK



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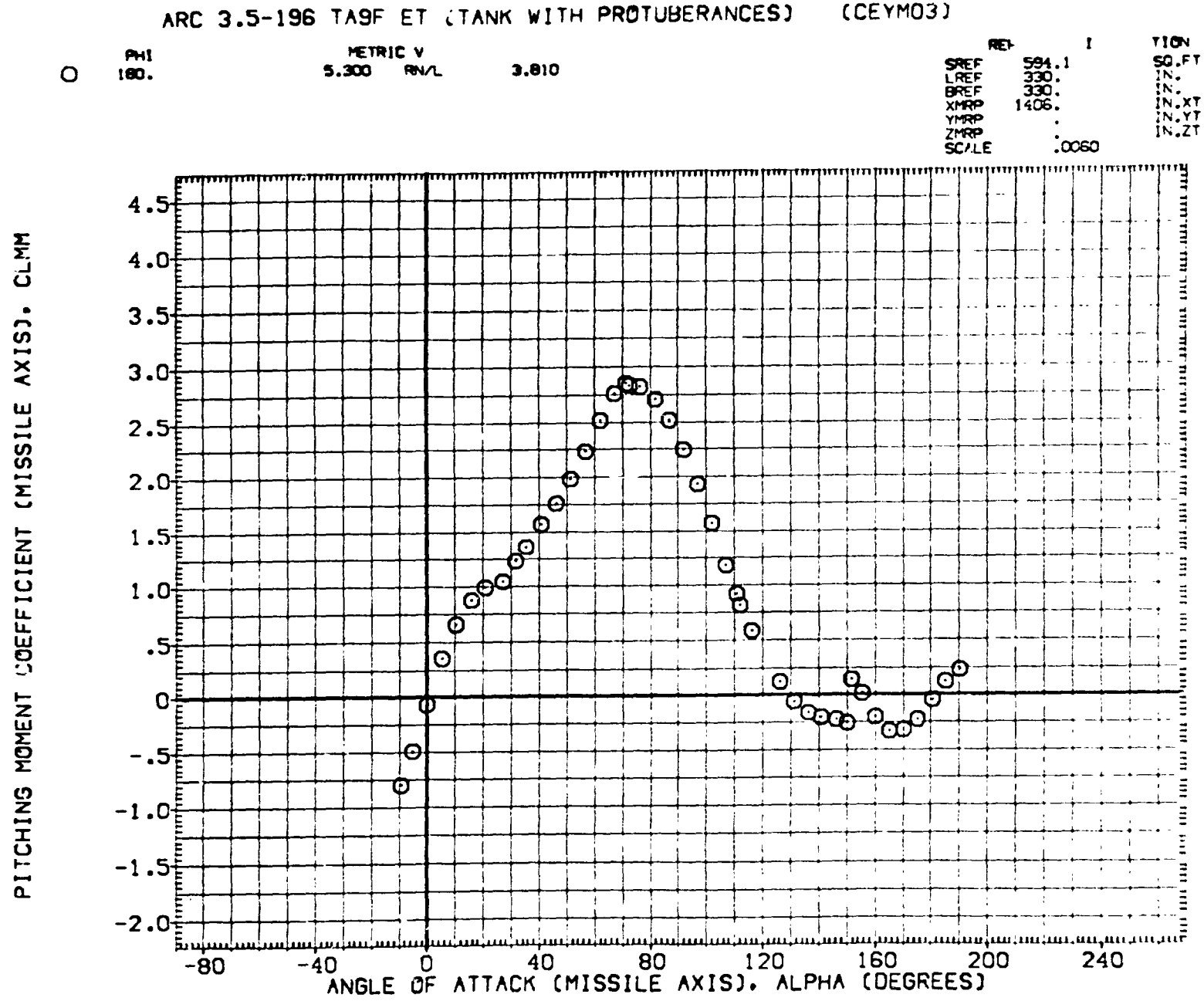

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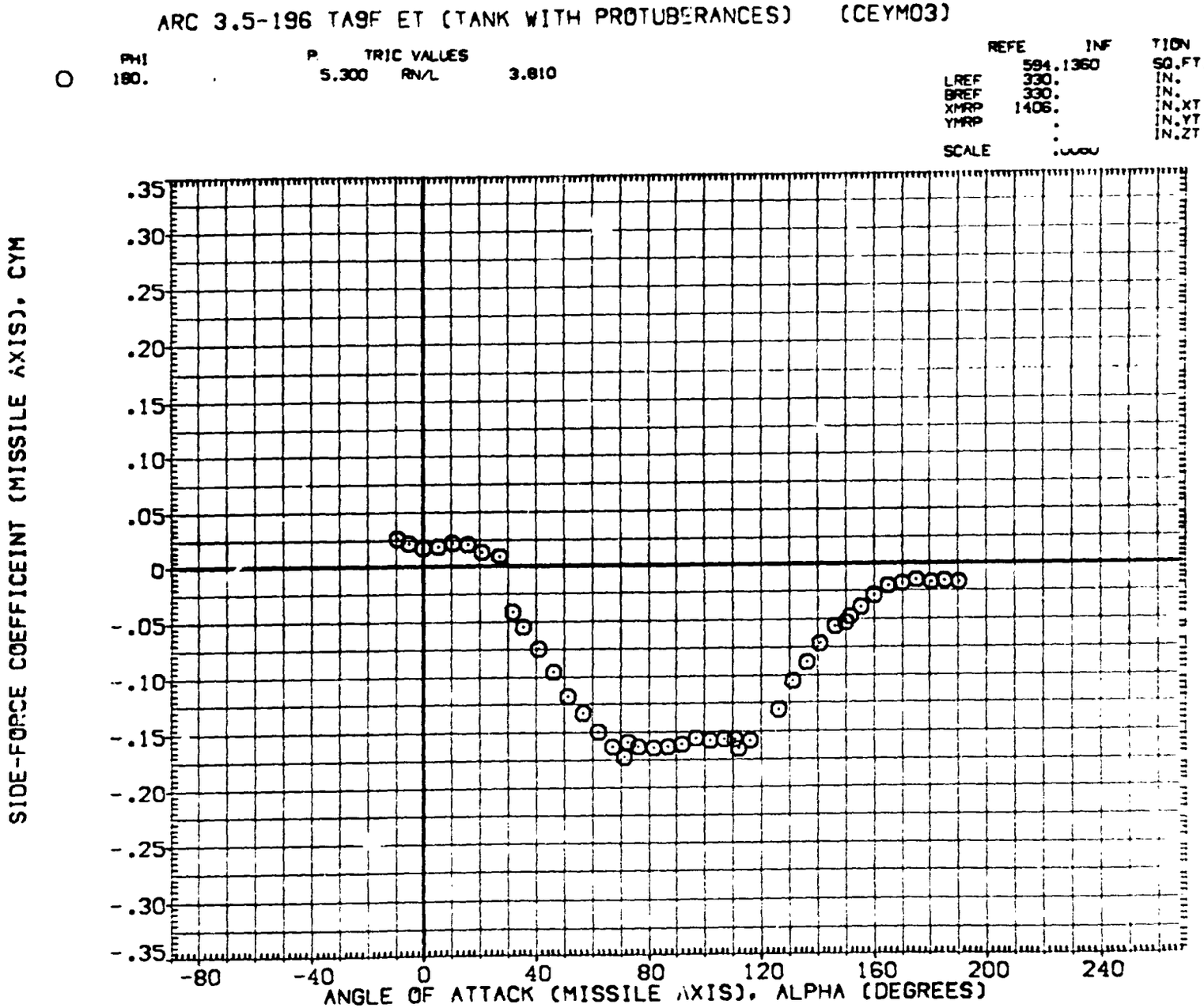

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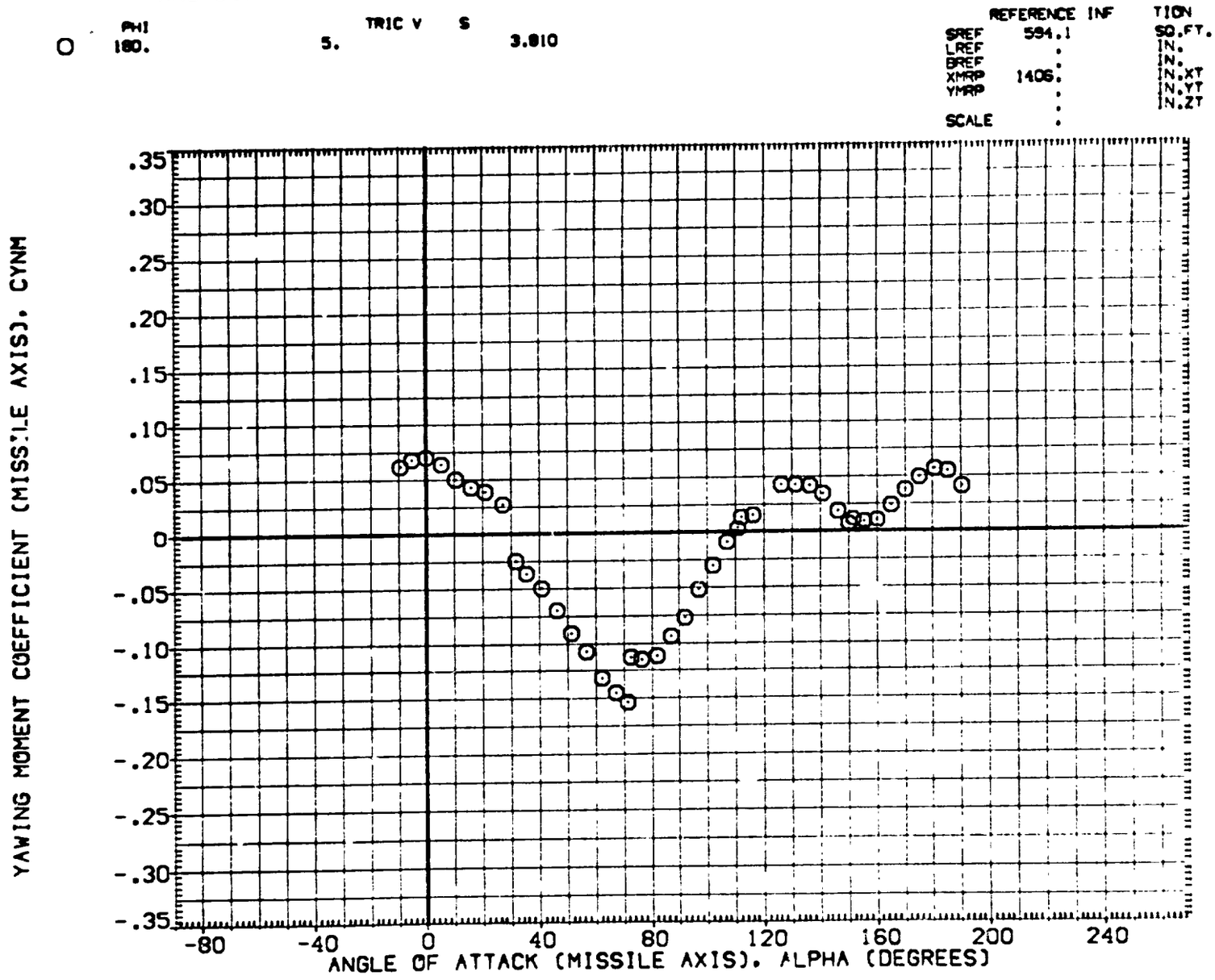

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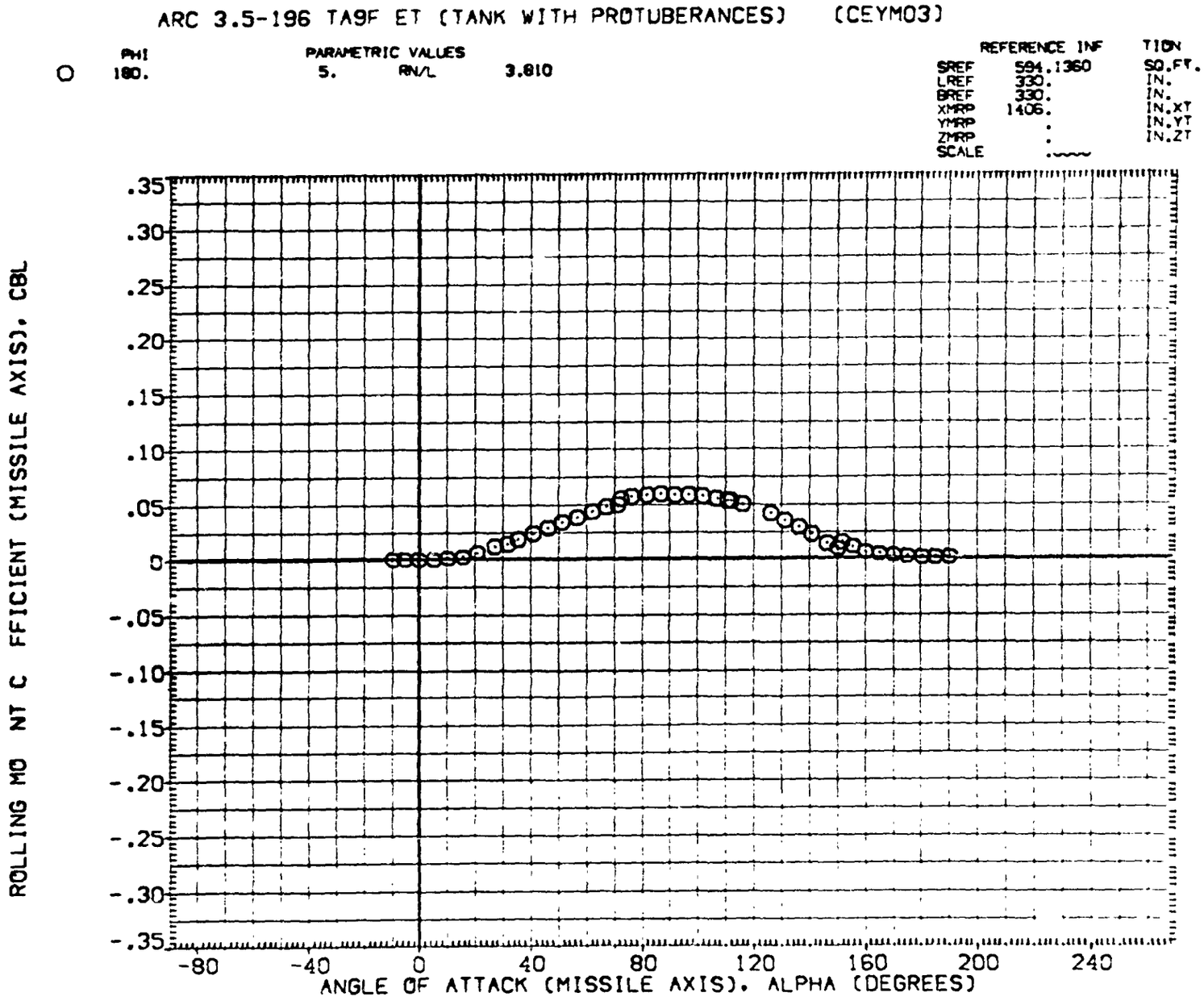

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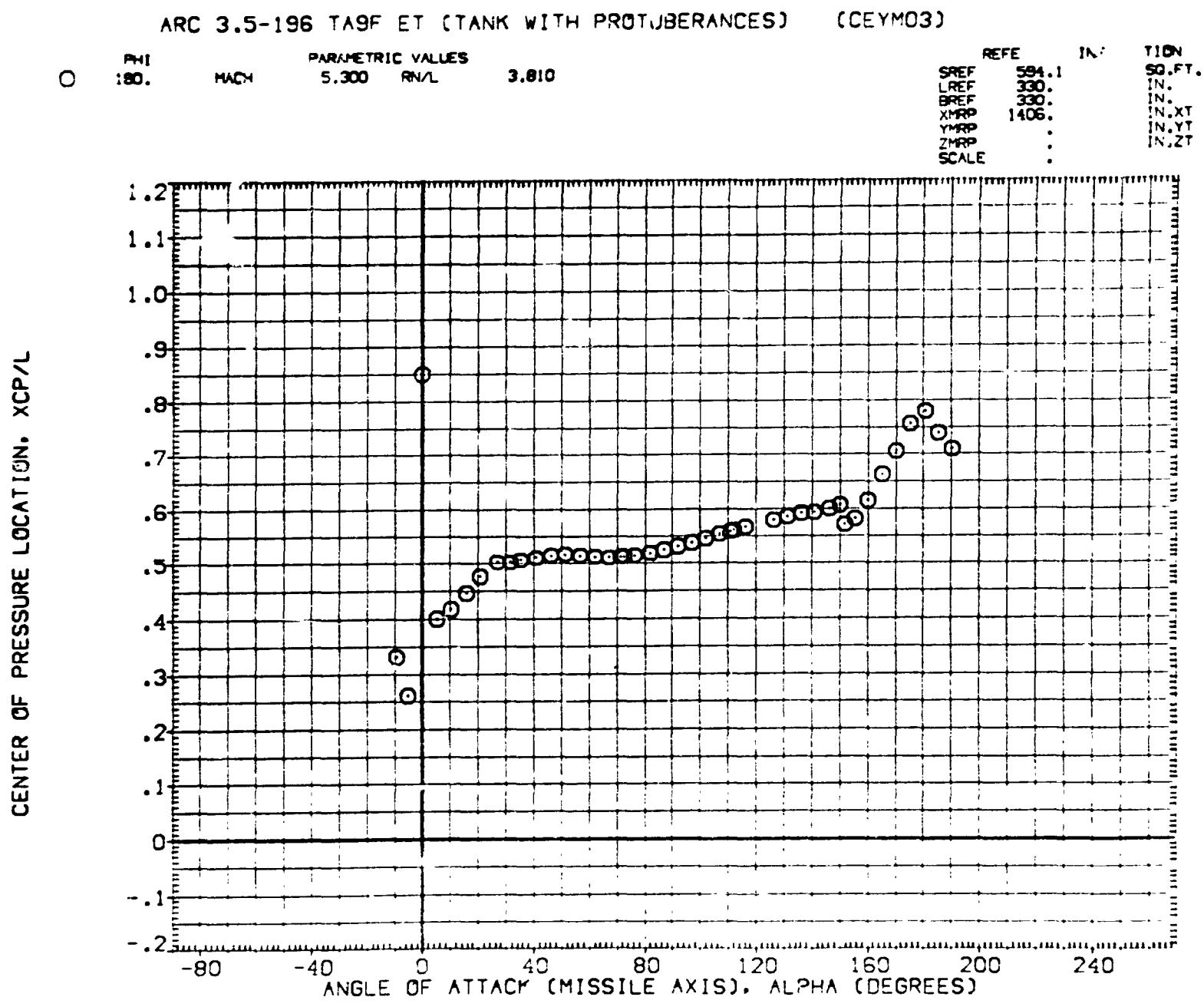

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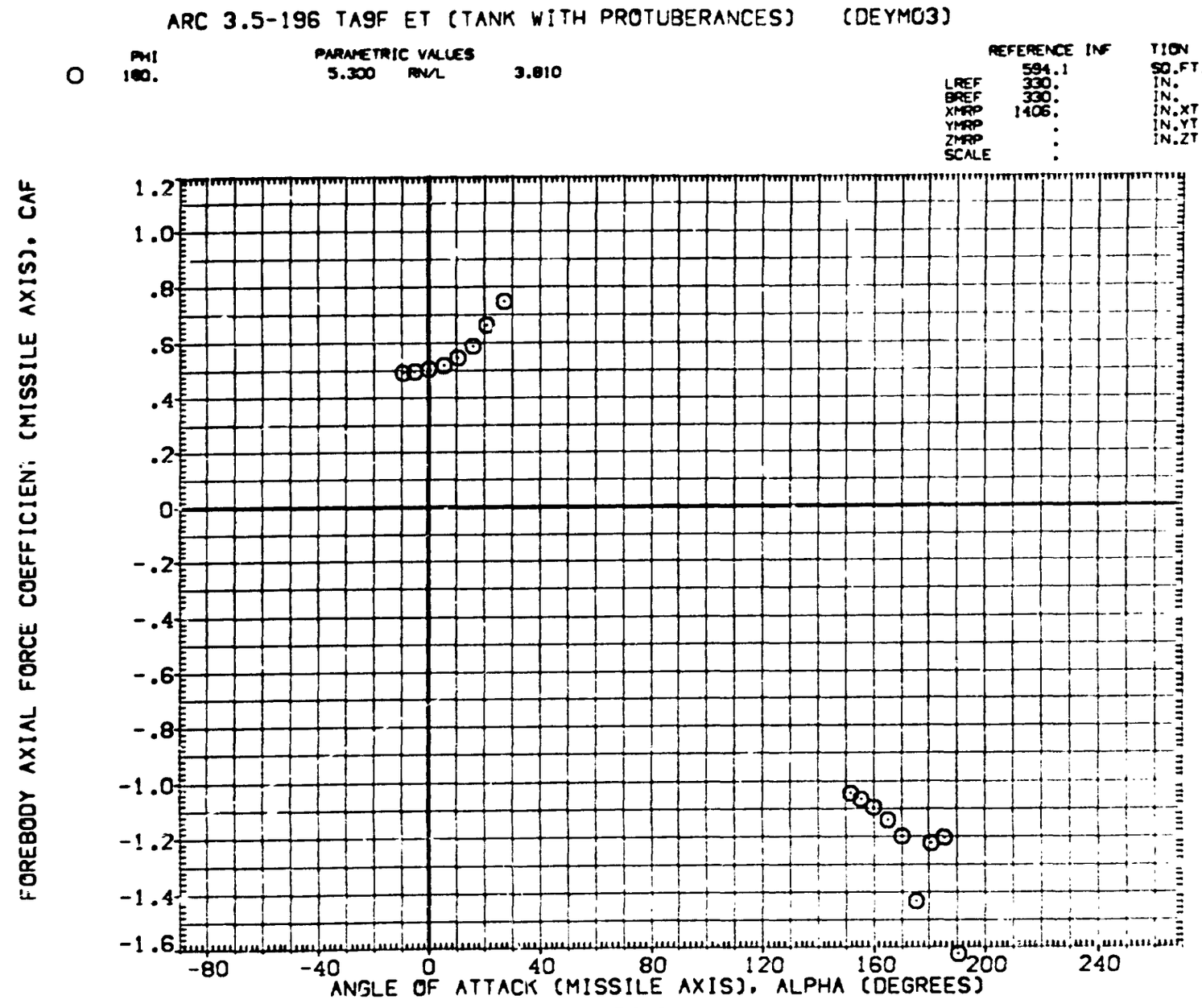
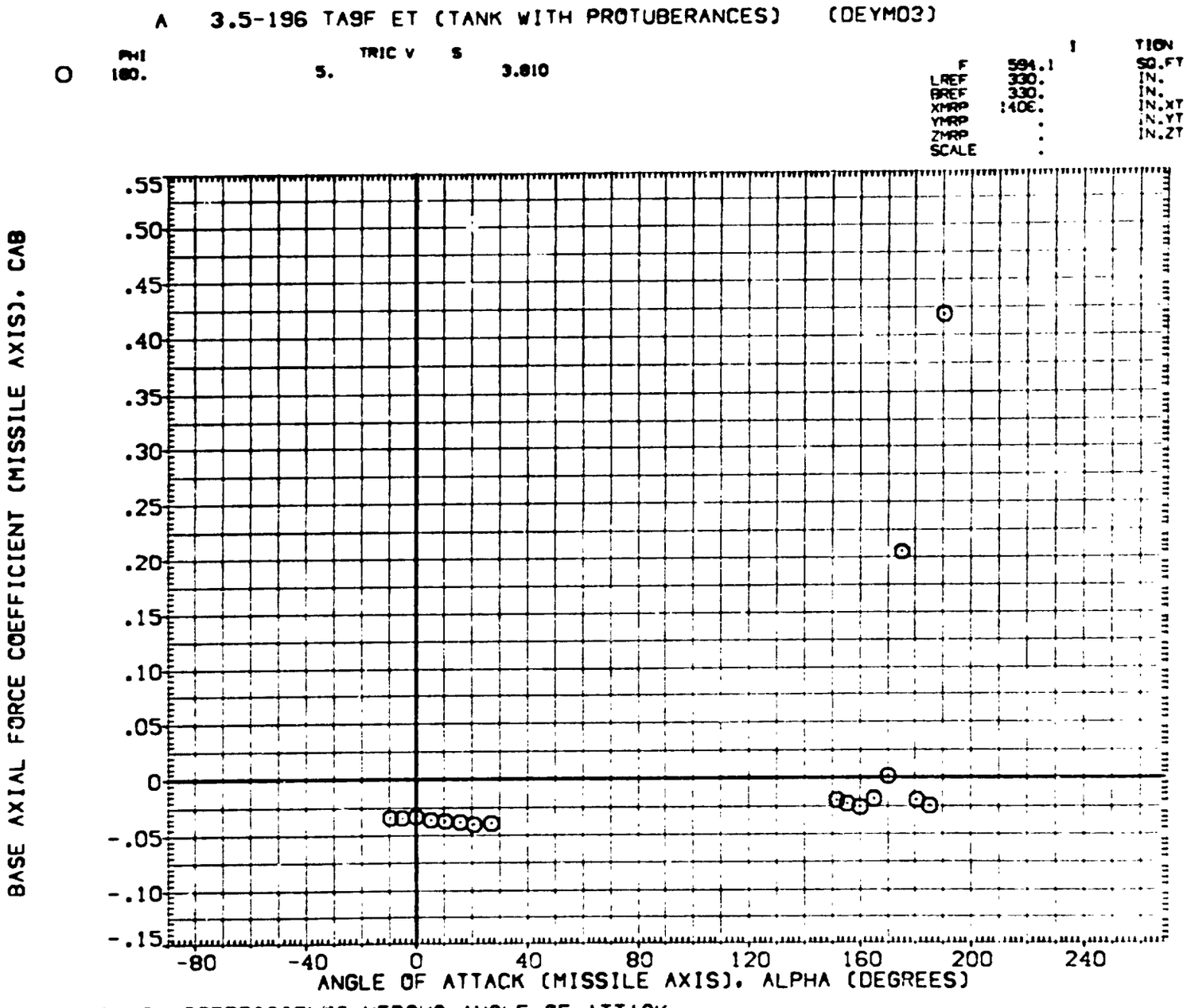


FIG. 6 COEFFICIENTS VERSUS ANGLE OF ATTACK



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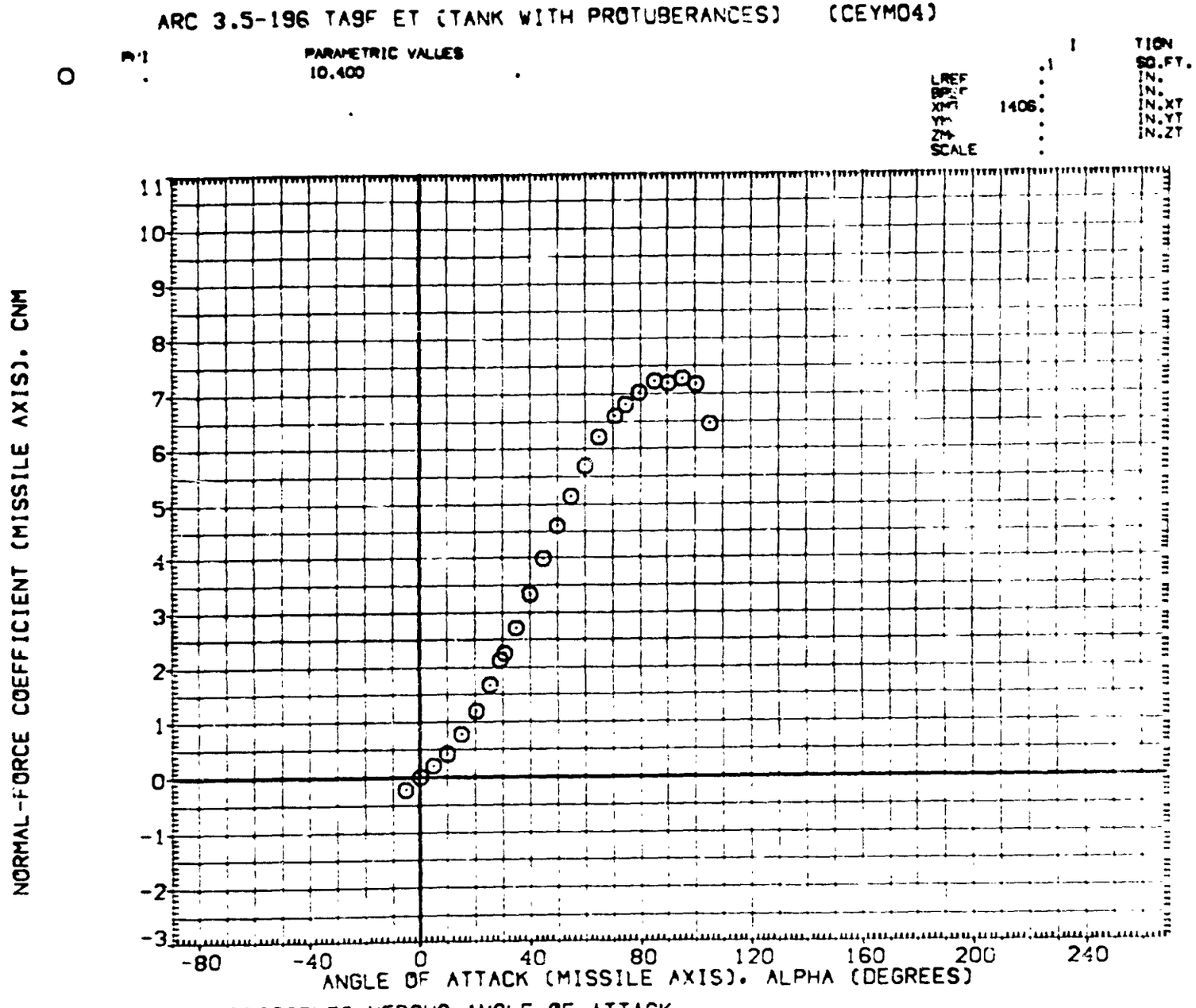

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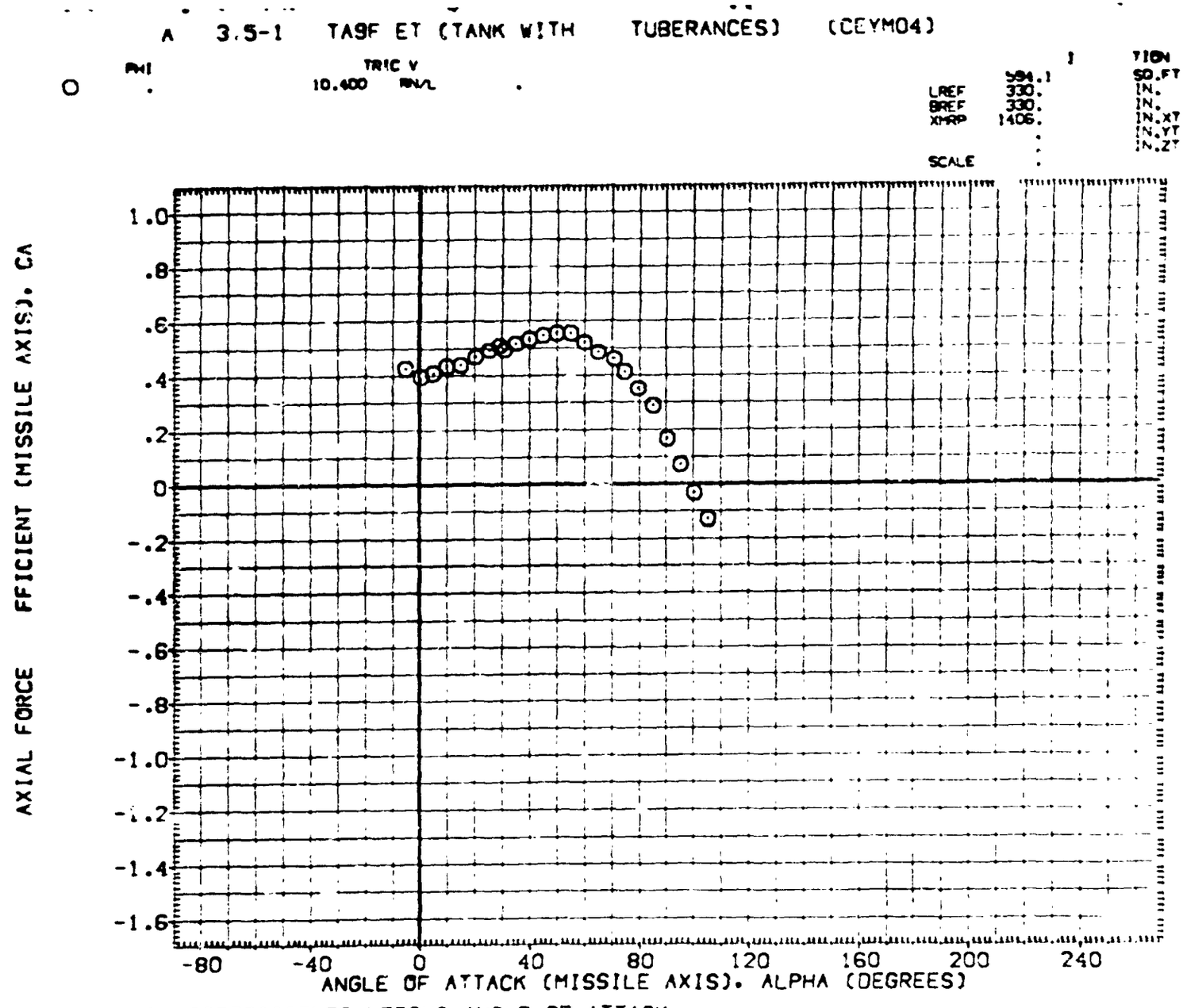

FIG. 7 COEFFICIENTS VERSUS ANGLE OF ATTACK

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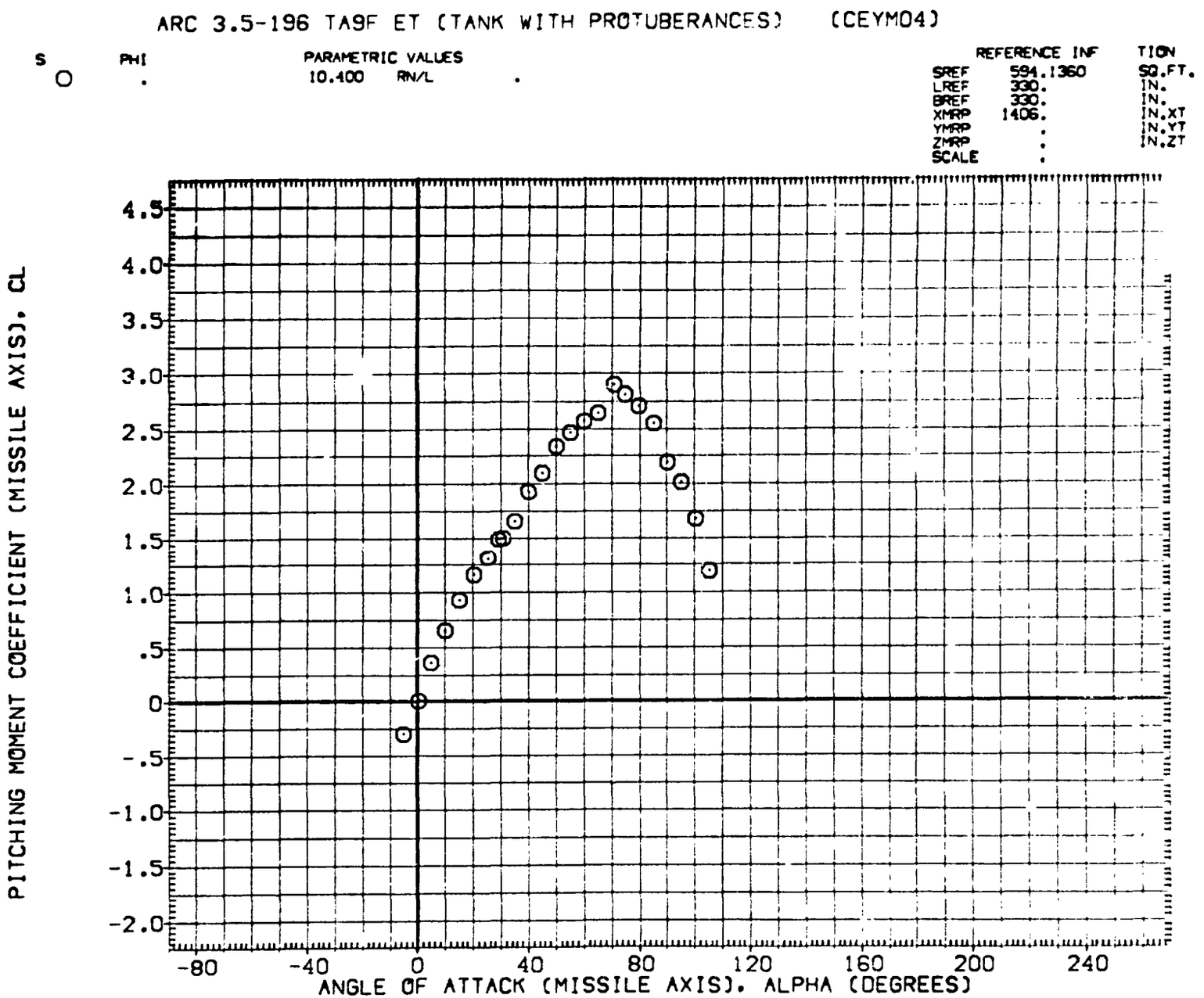

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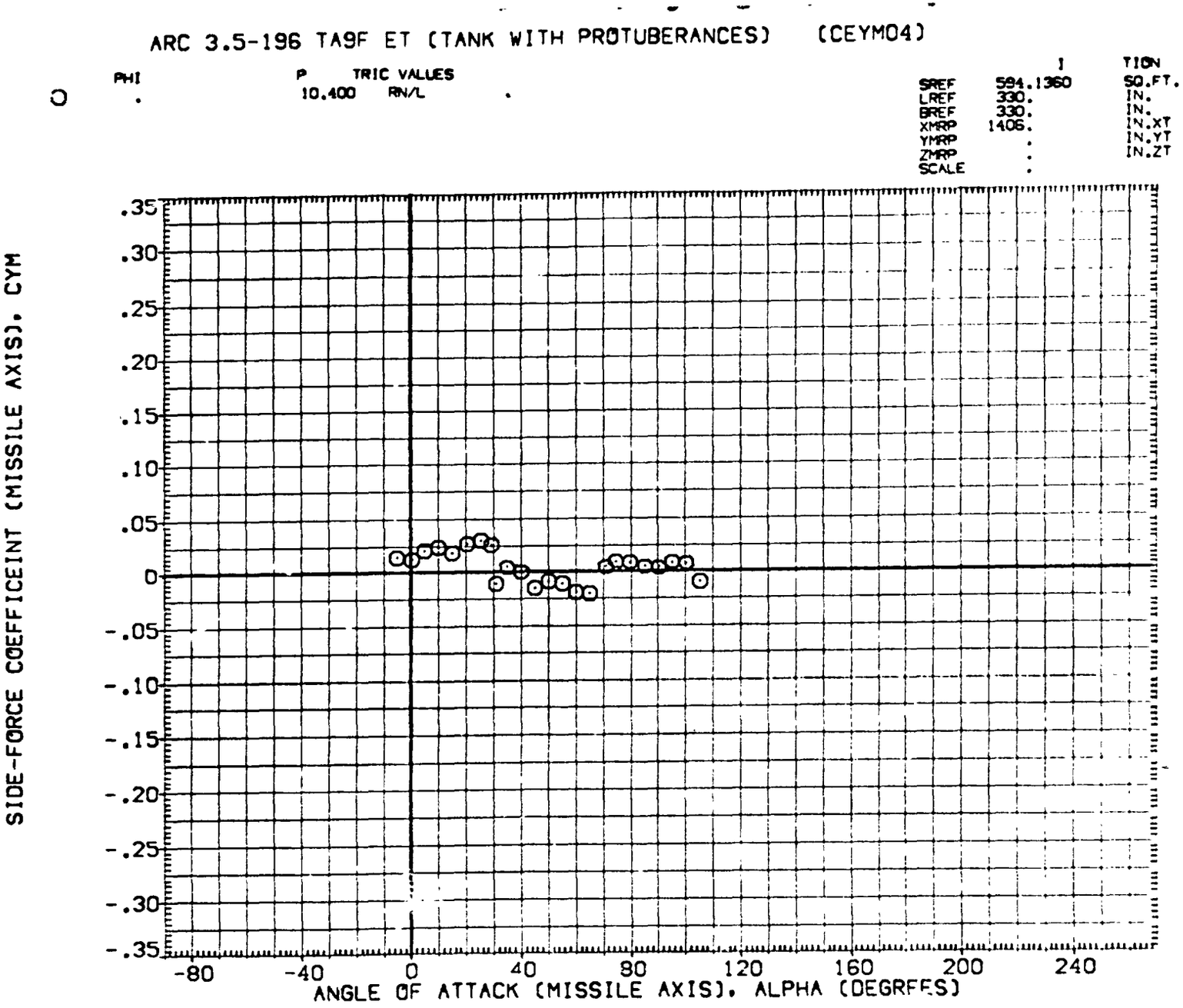

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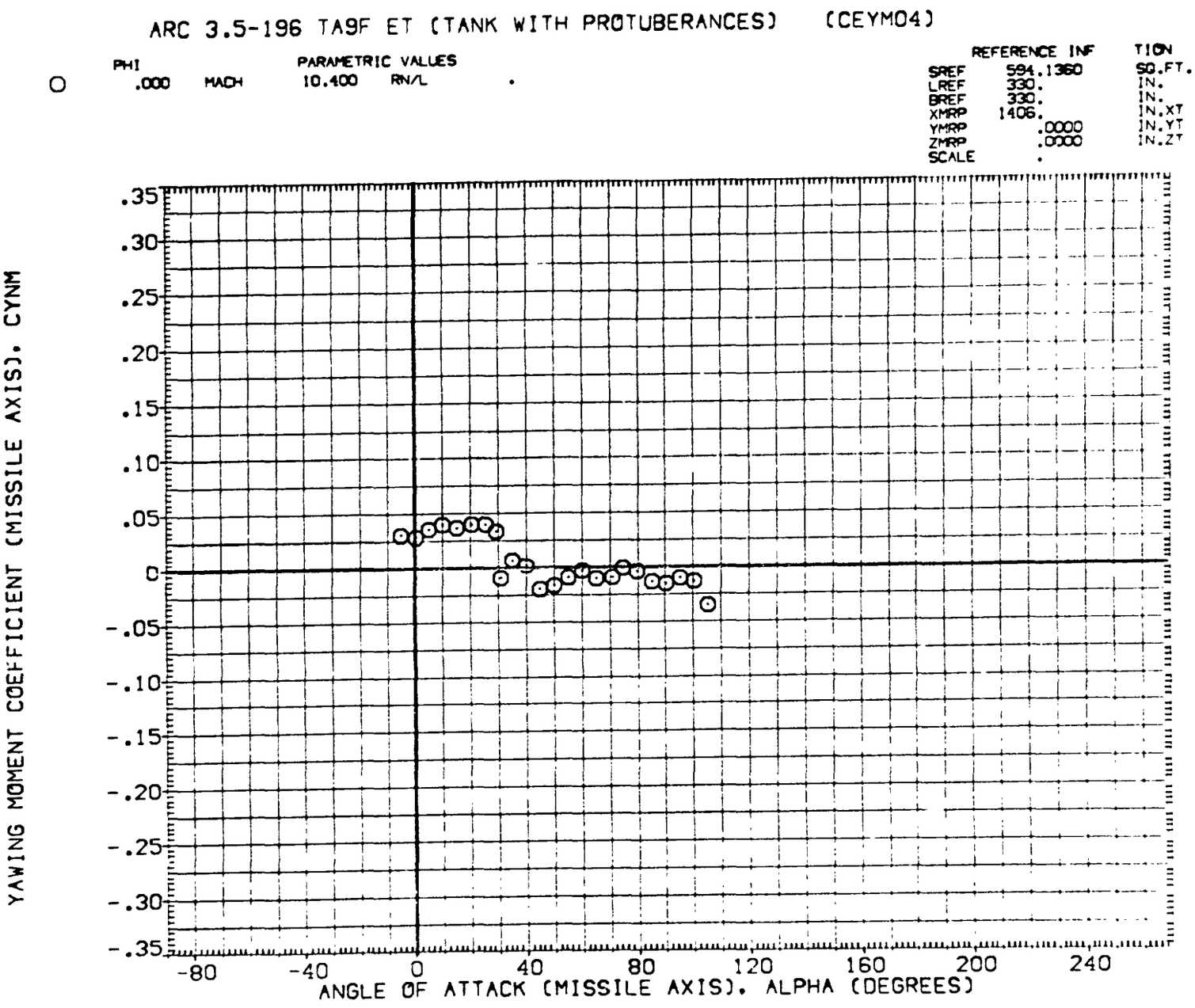
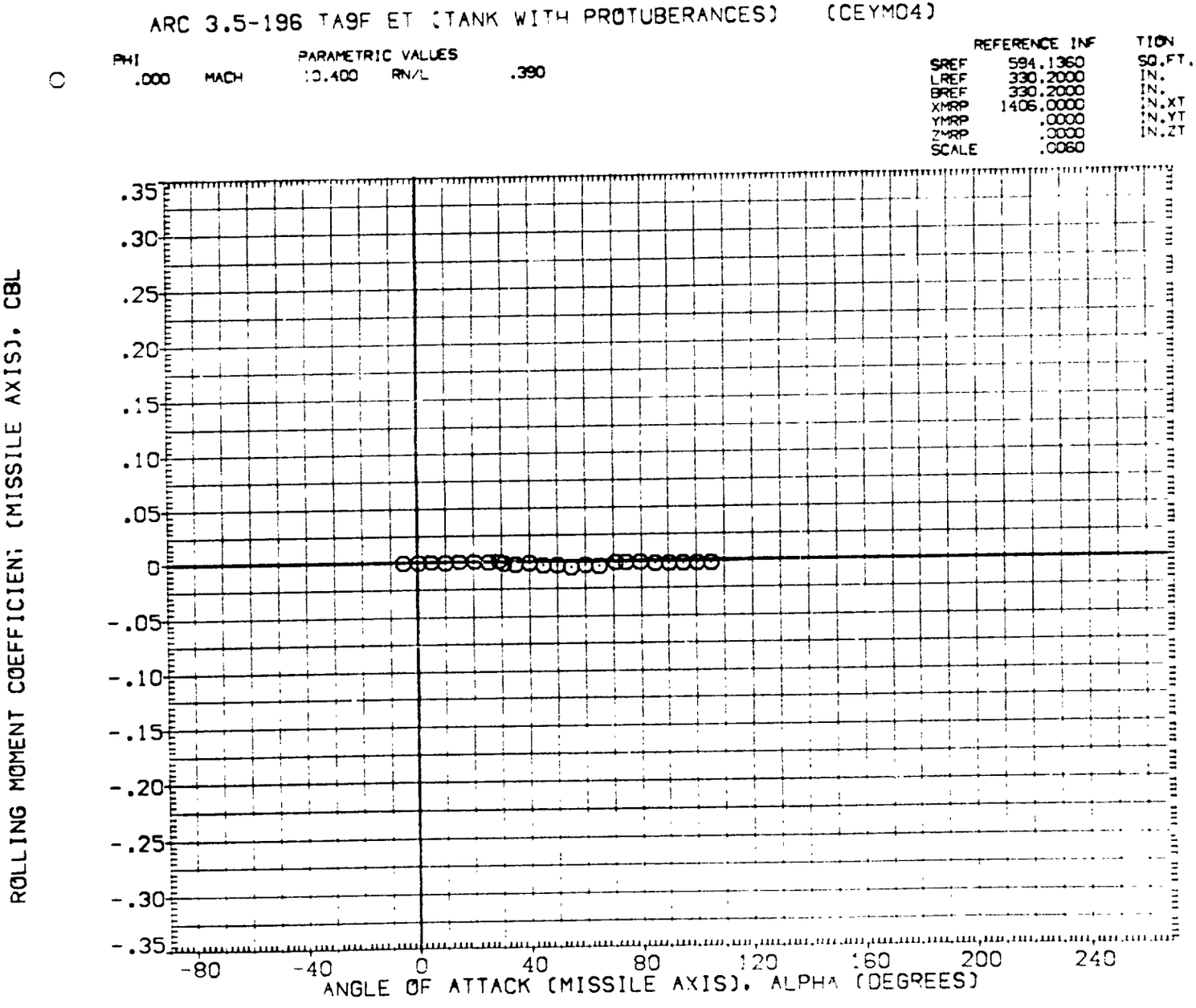


FIG. 7 COEFFICIENTS VERSUS ANGLE OF ATTACK



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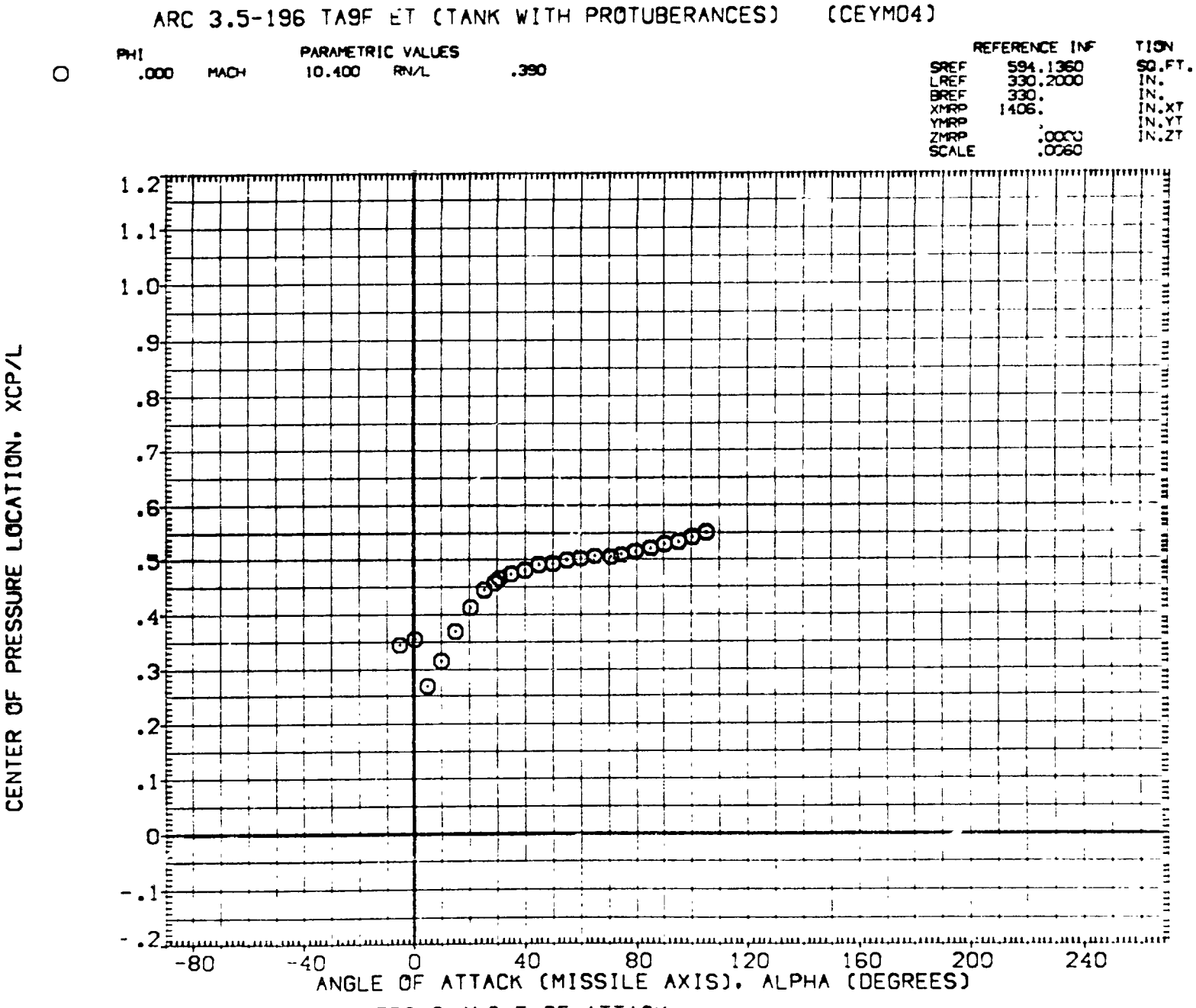

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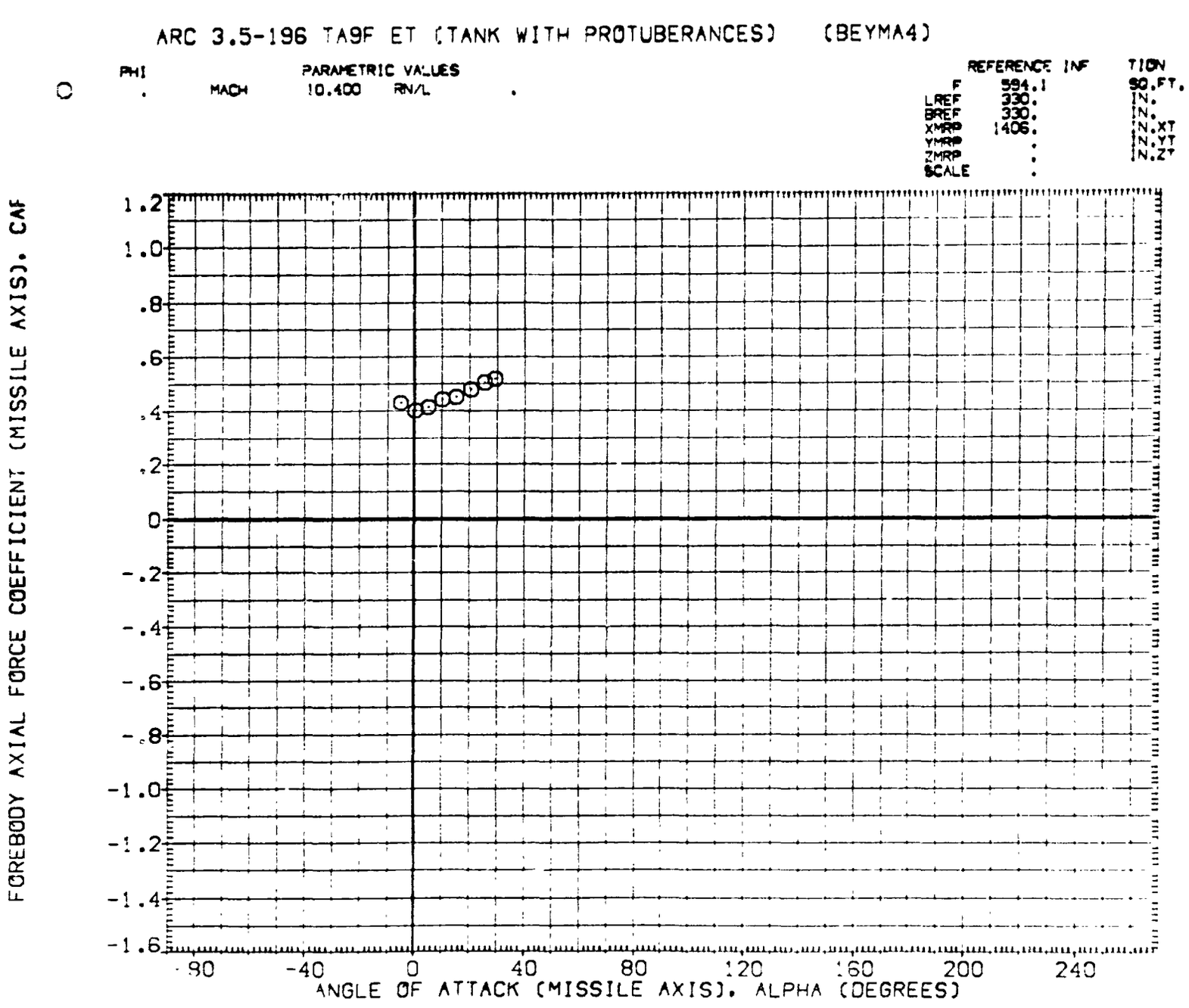

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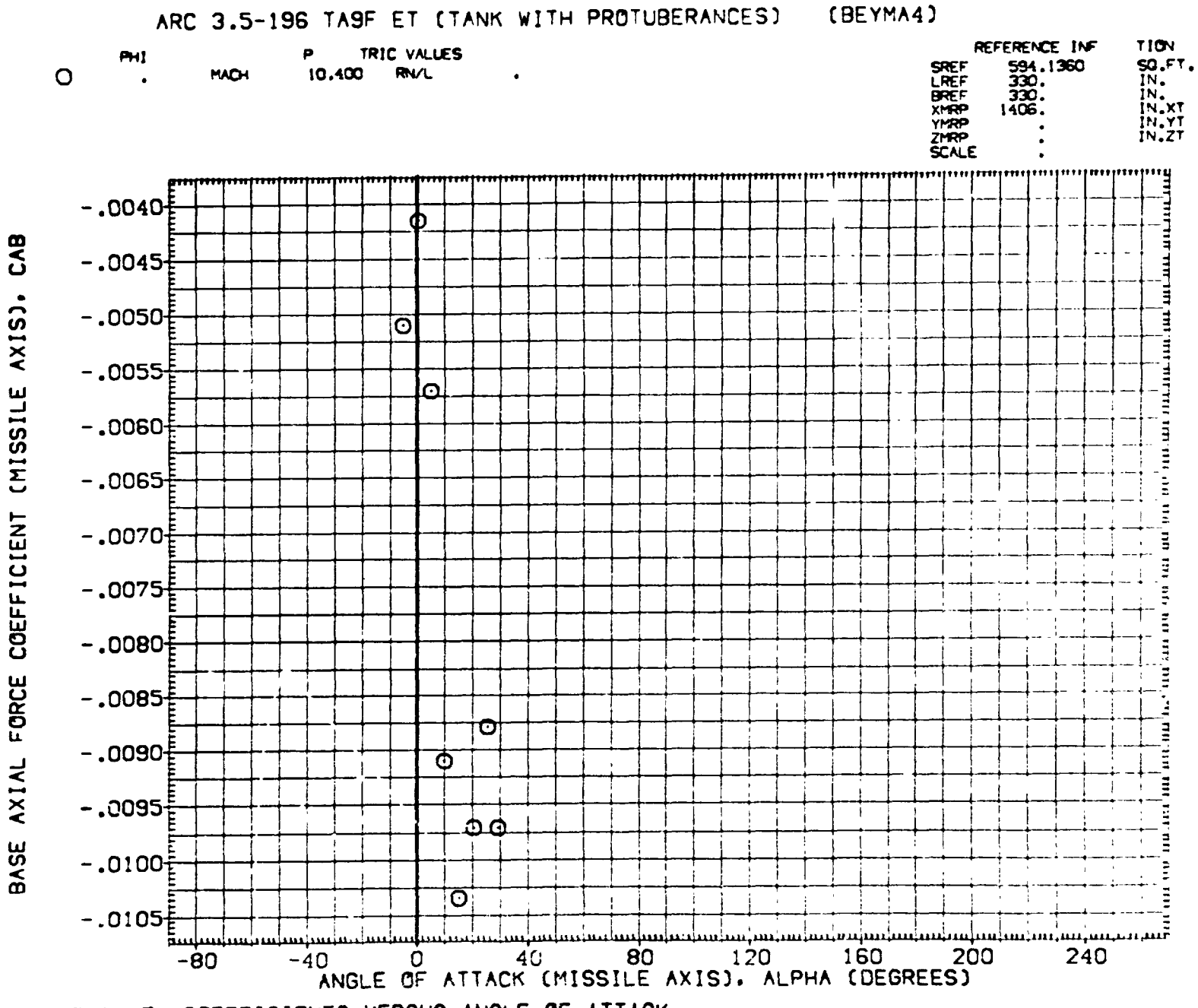

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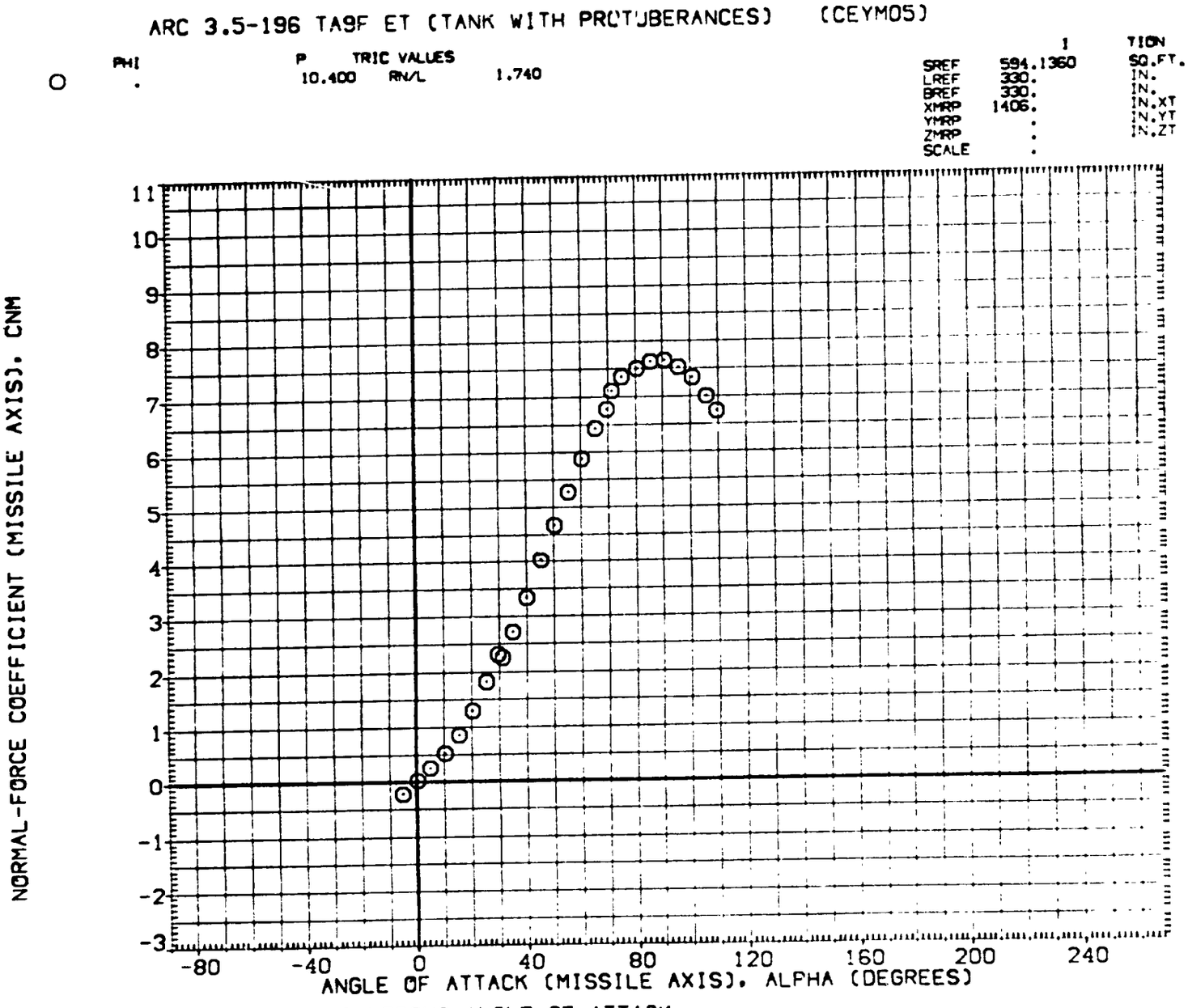

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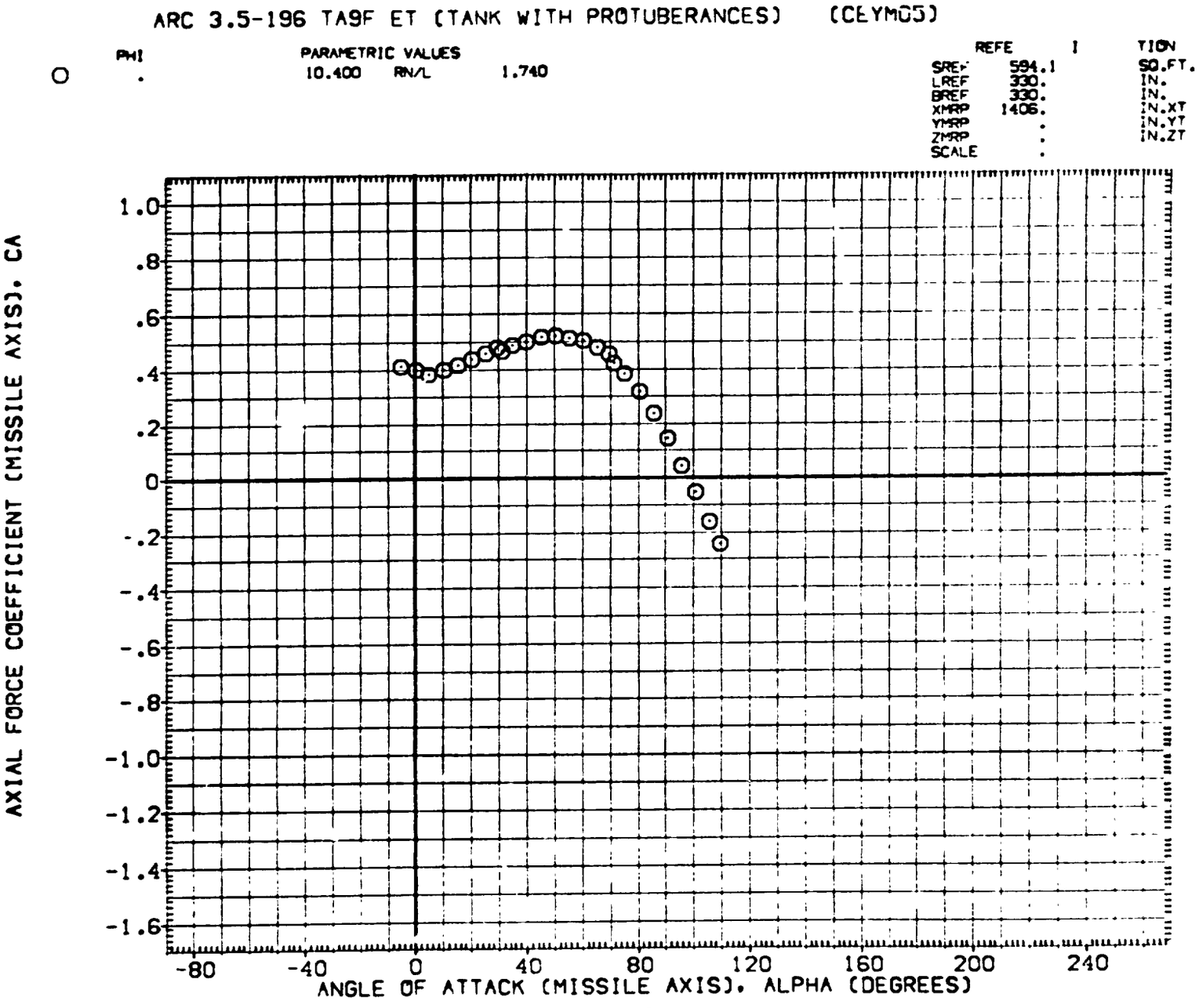

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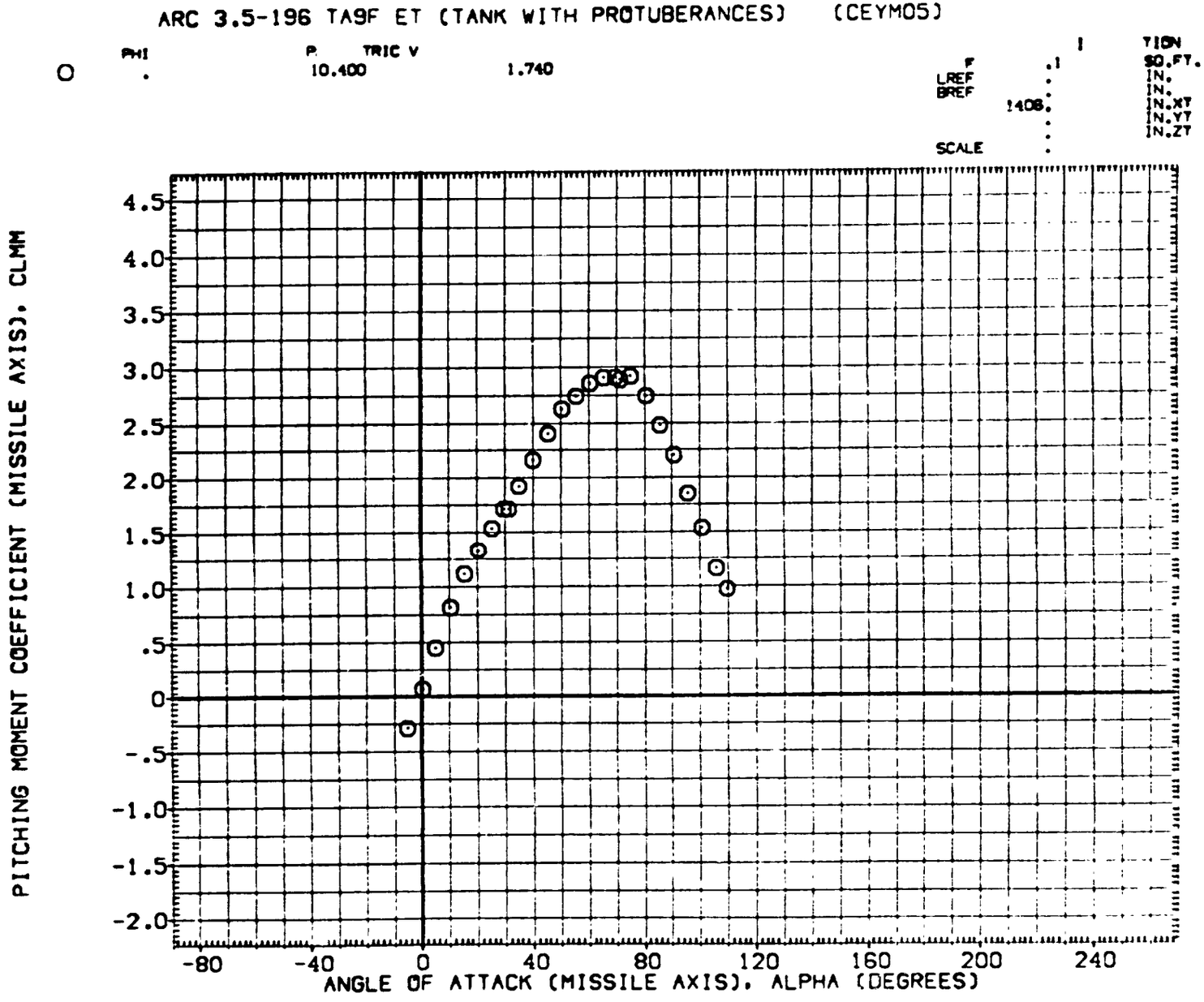

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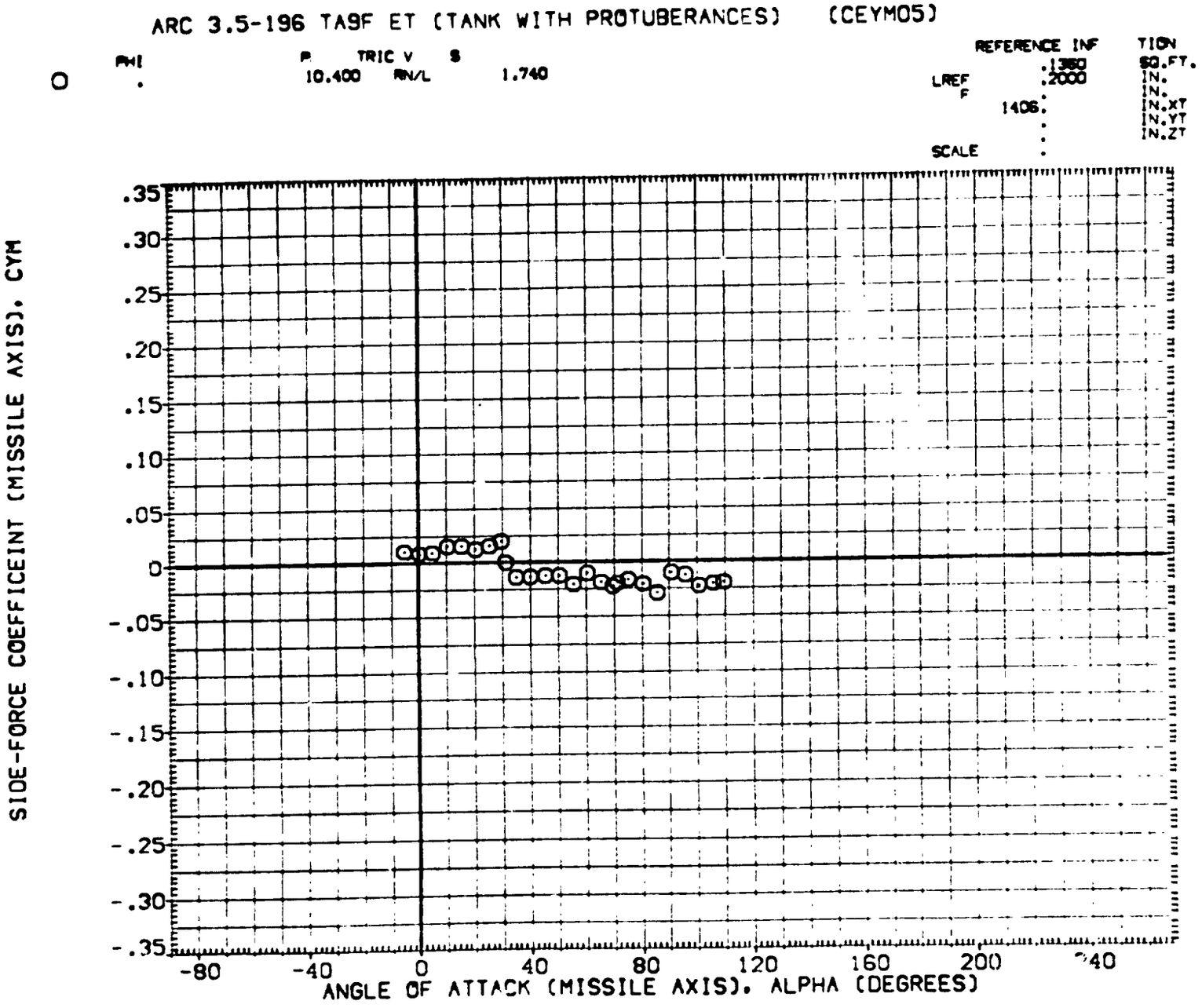
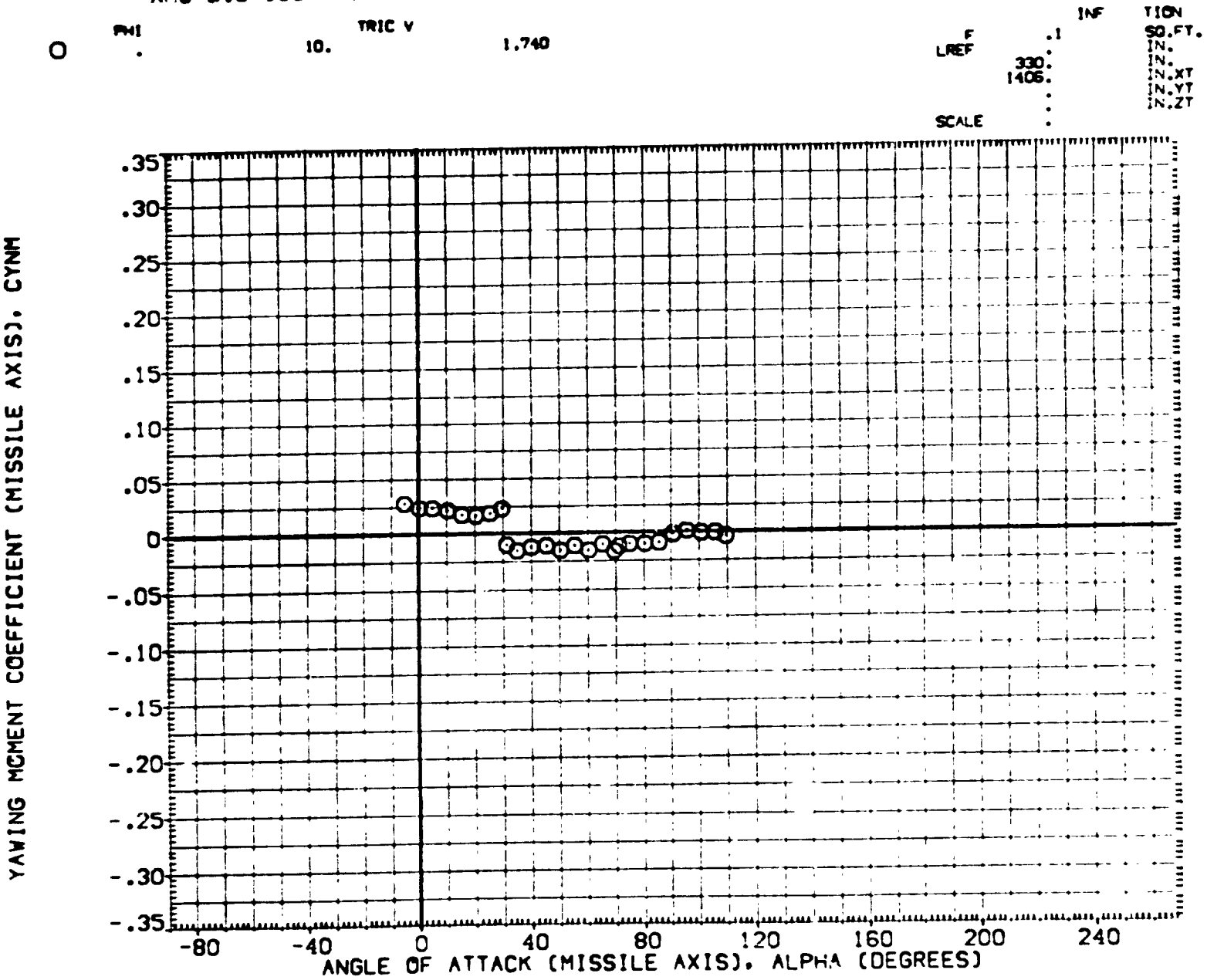


FIG. 8 COEFFICIENTS VE US ANGLE OF ATTACK



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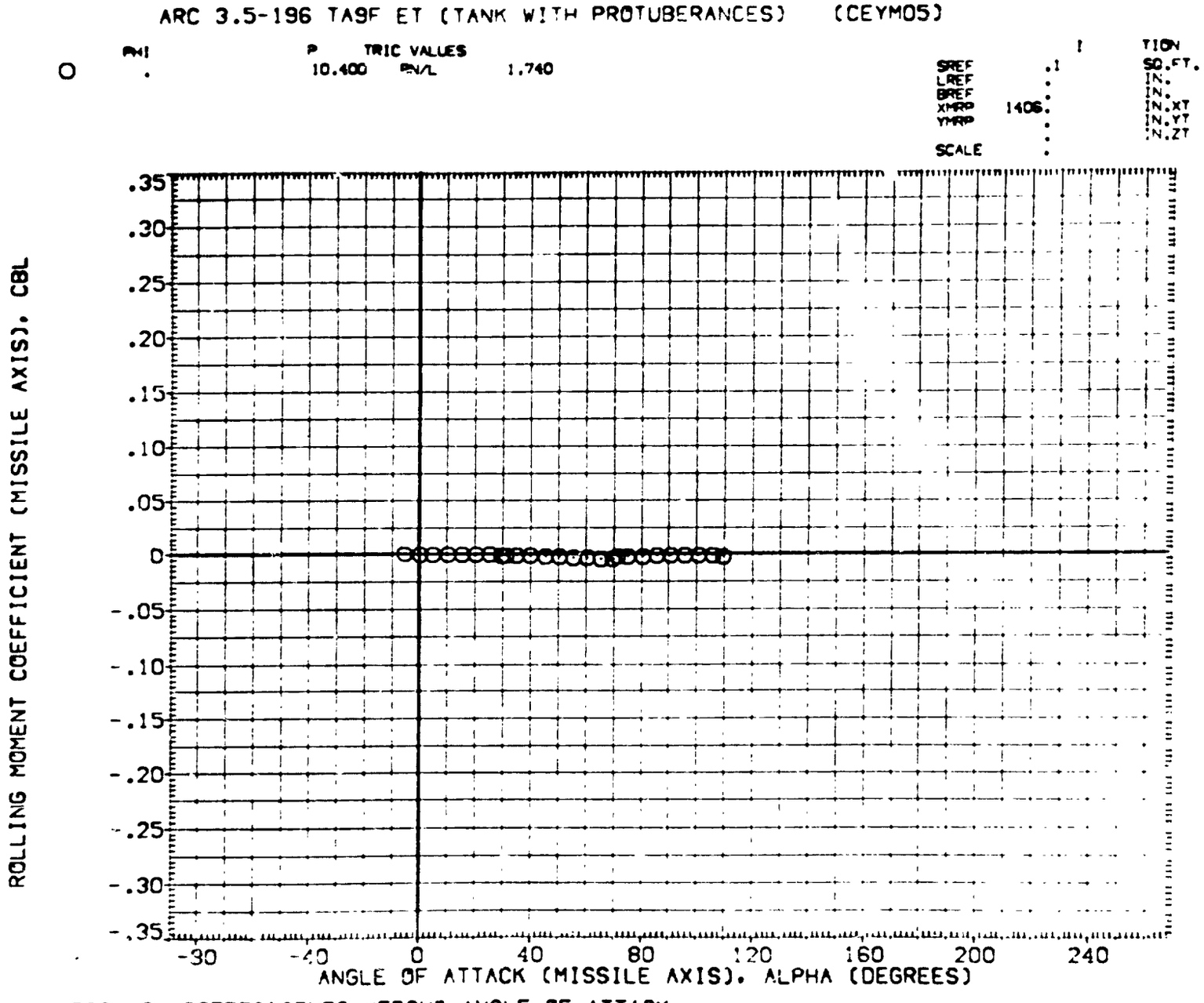

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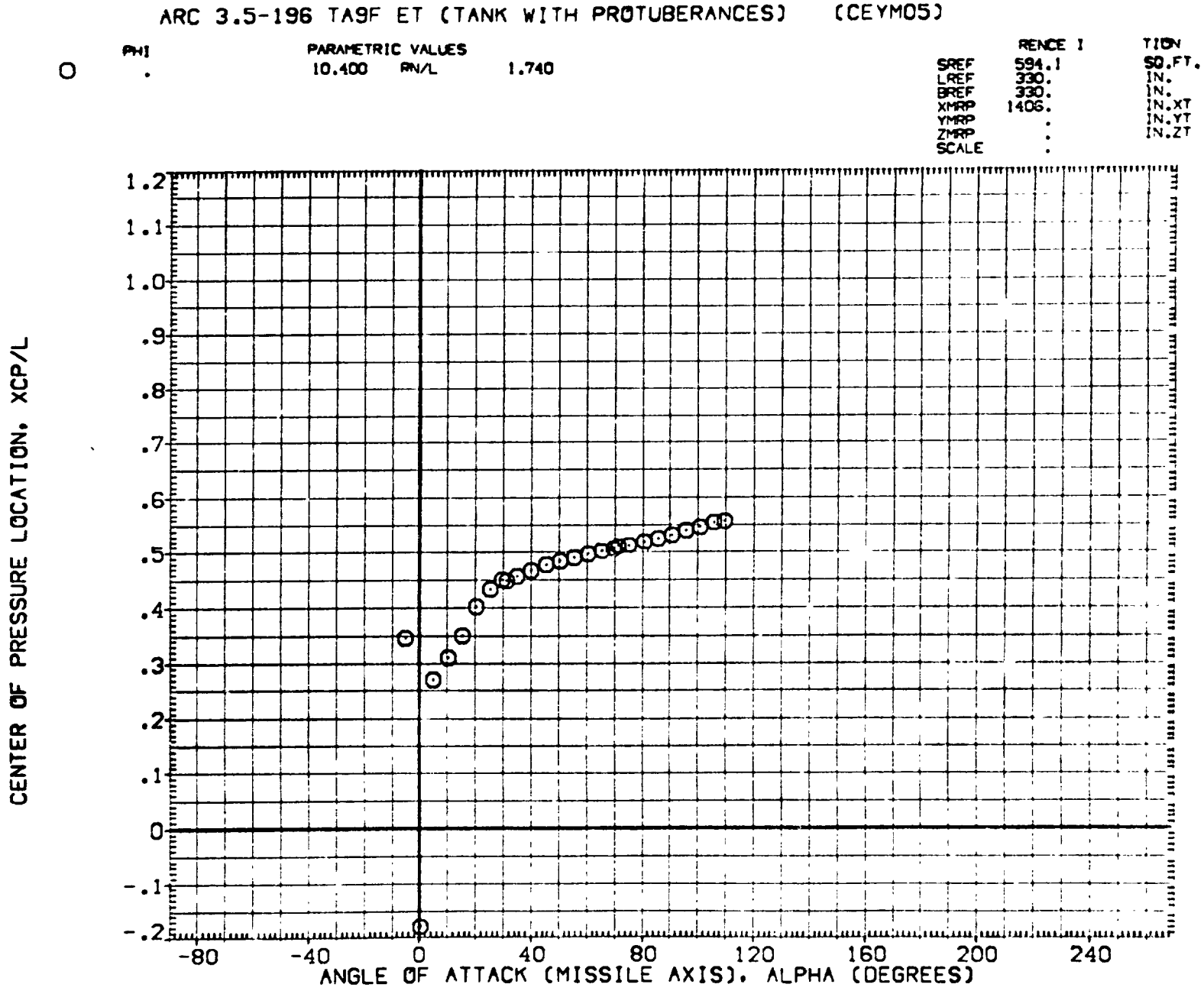

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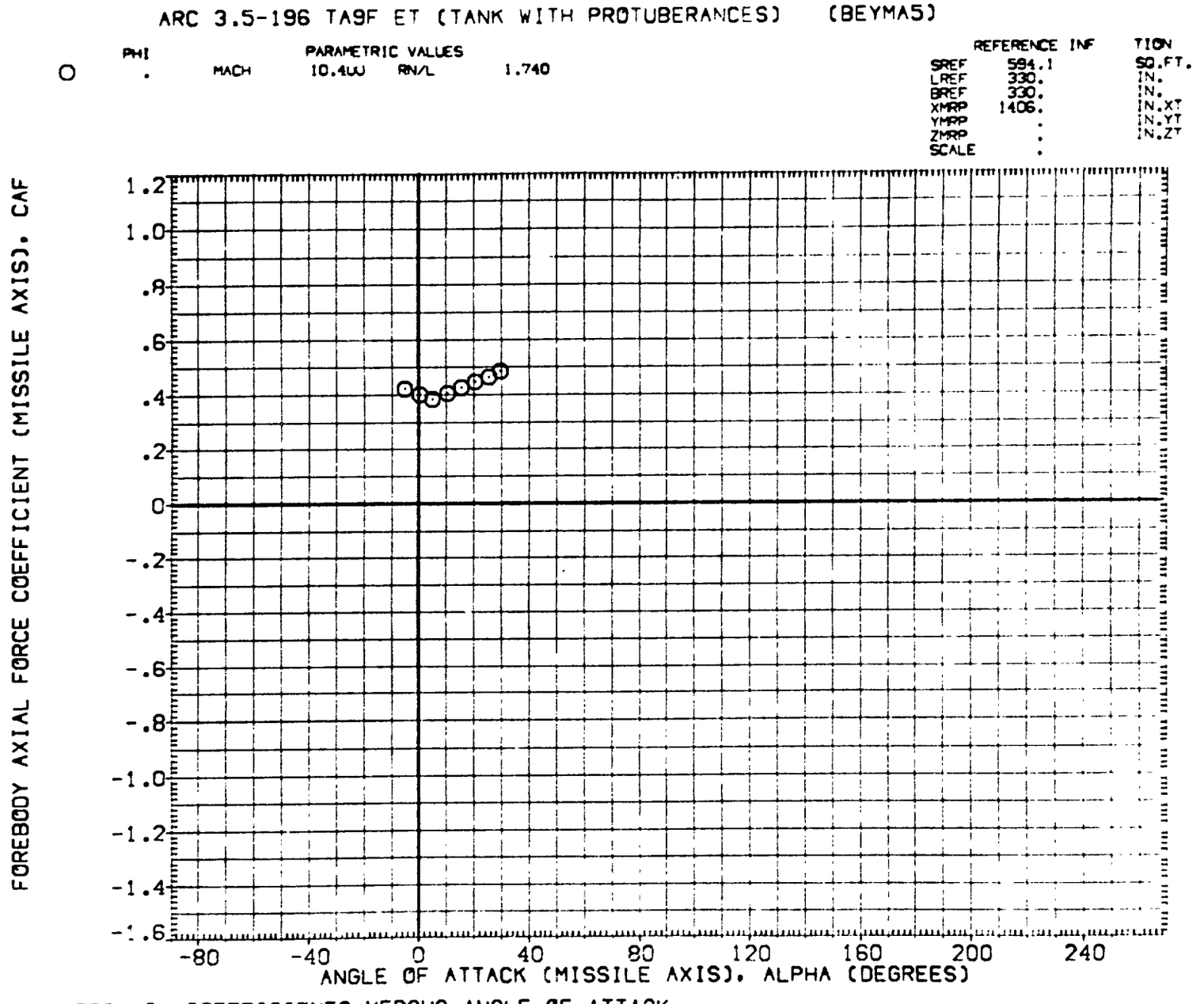

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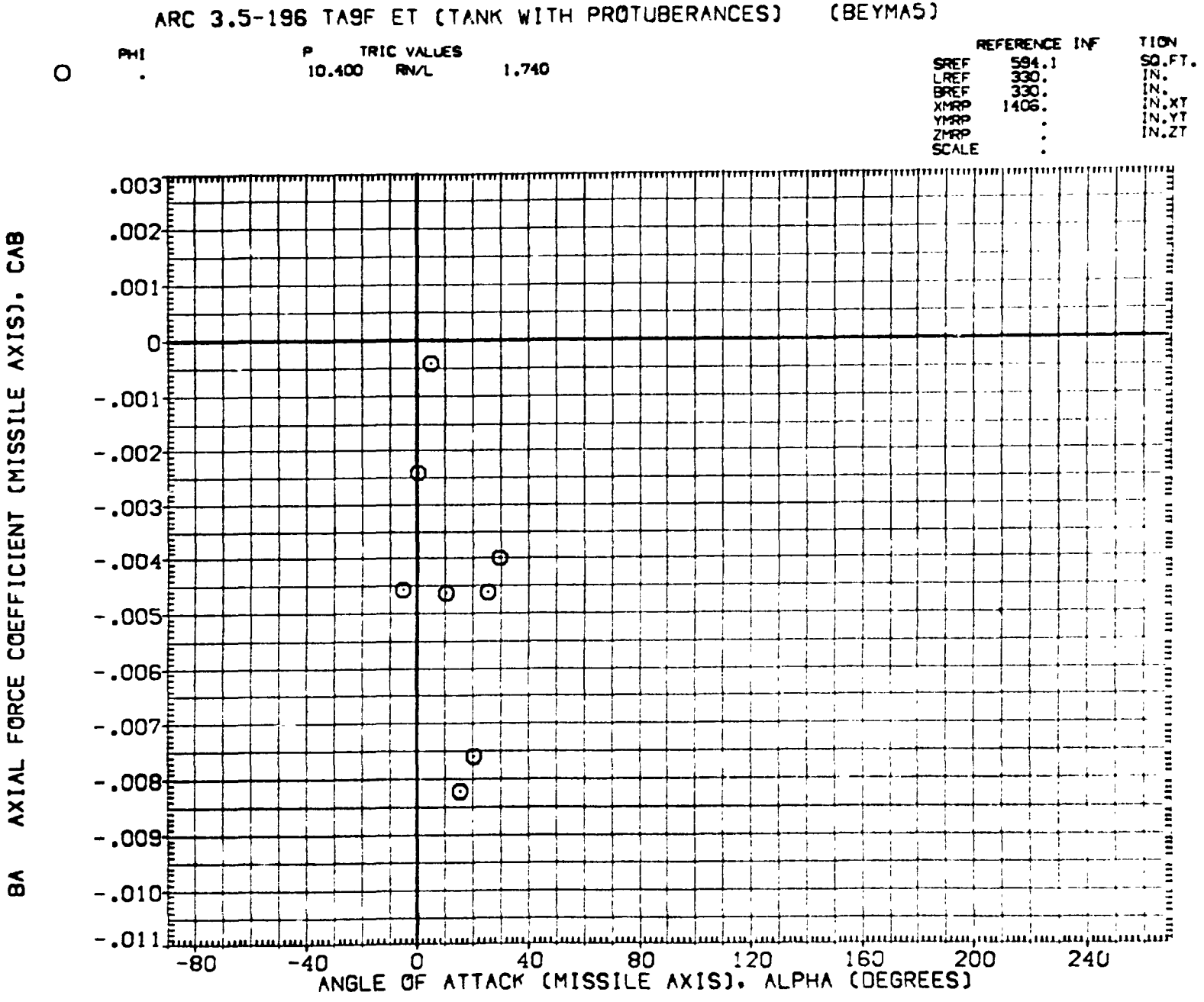

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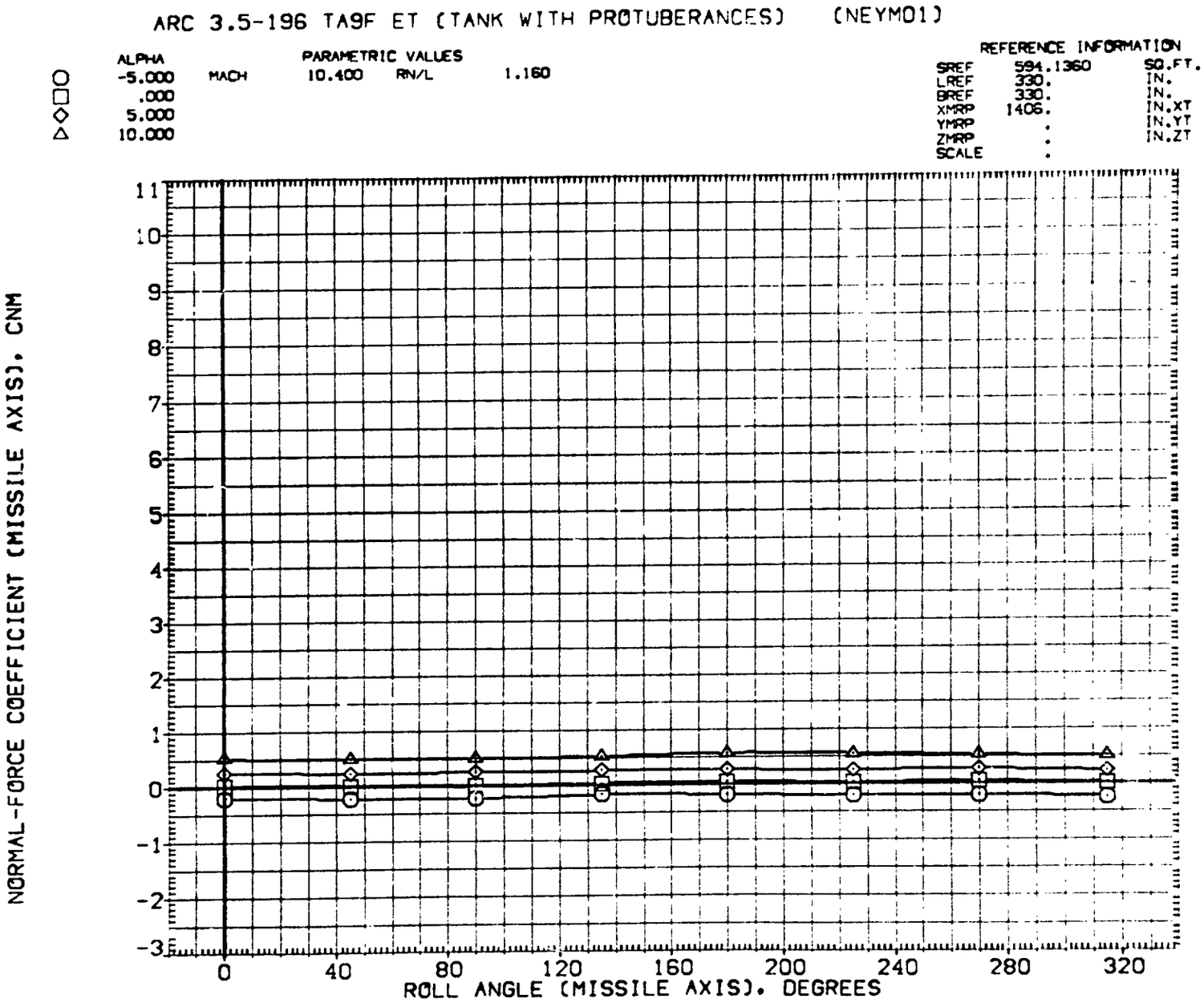
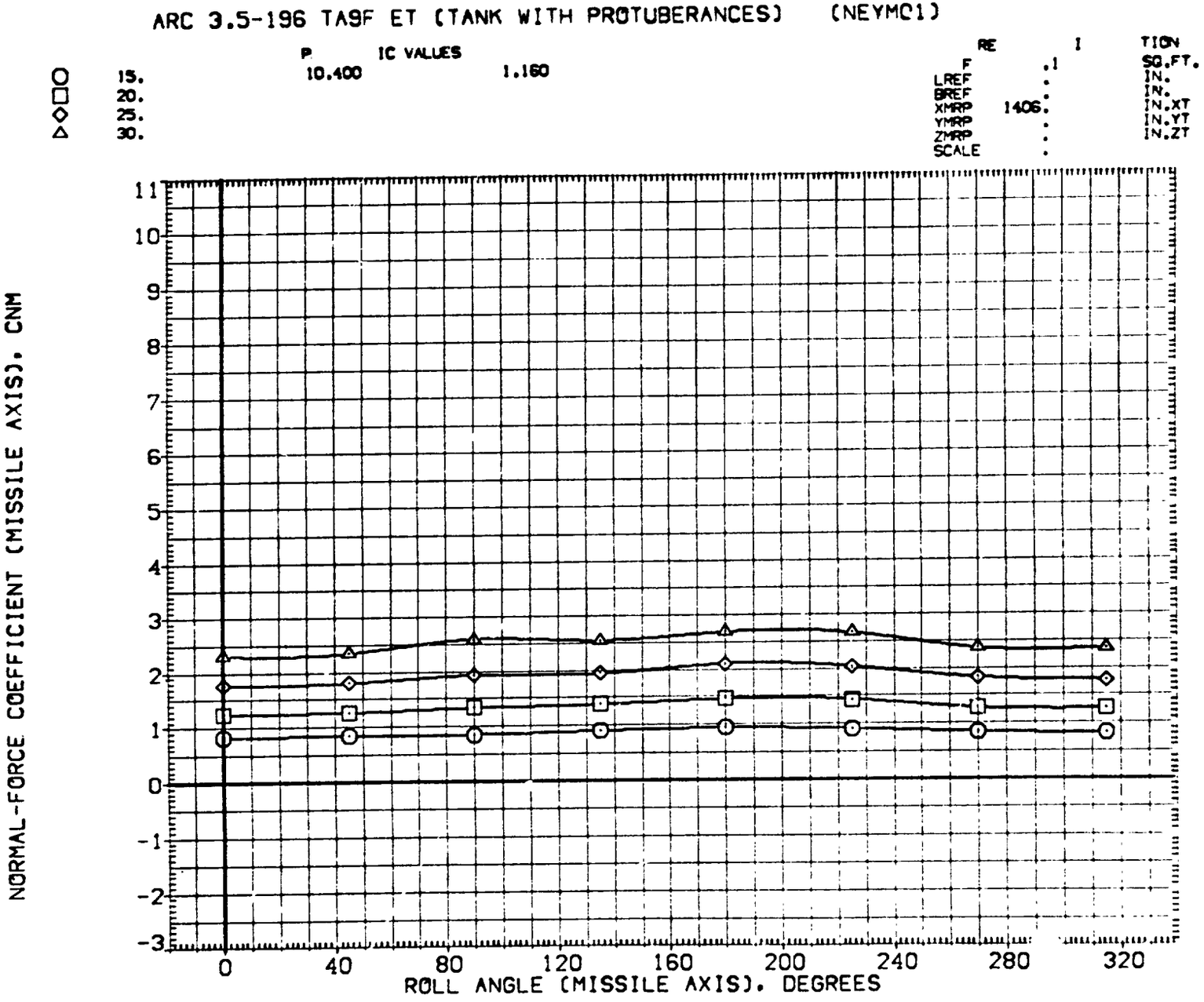


FIG. 9 COEFFICIENTS VERSUS ANGLE OF ROLL



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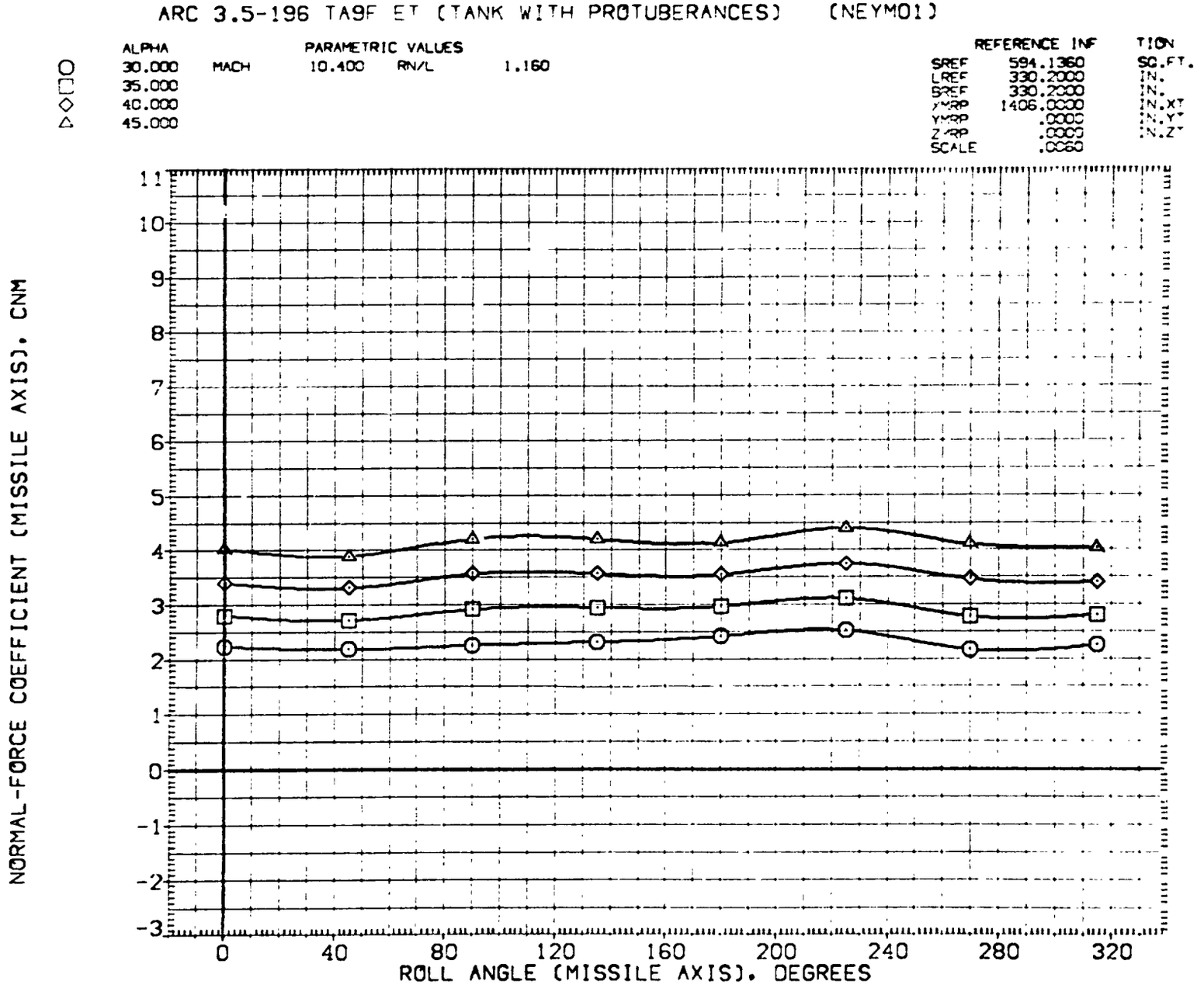


FIG. 9 COEFFICIENTS VERSUS ANGLE OF ROLL

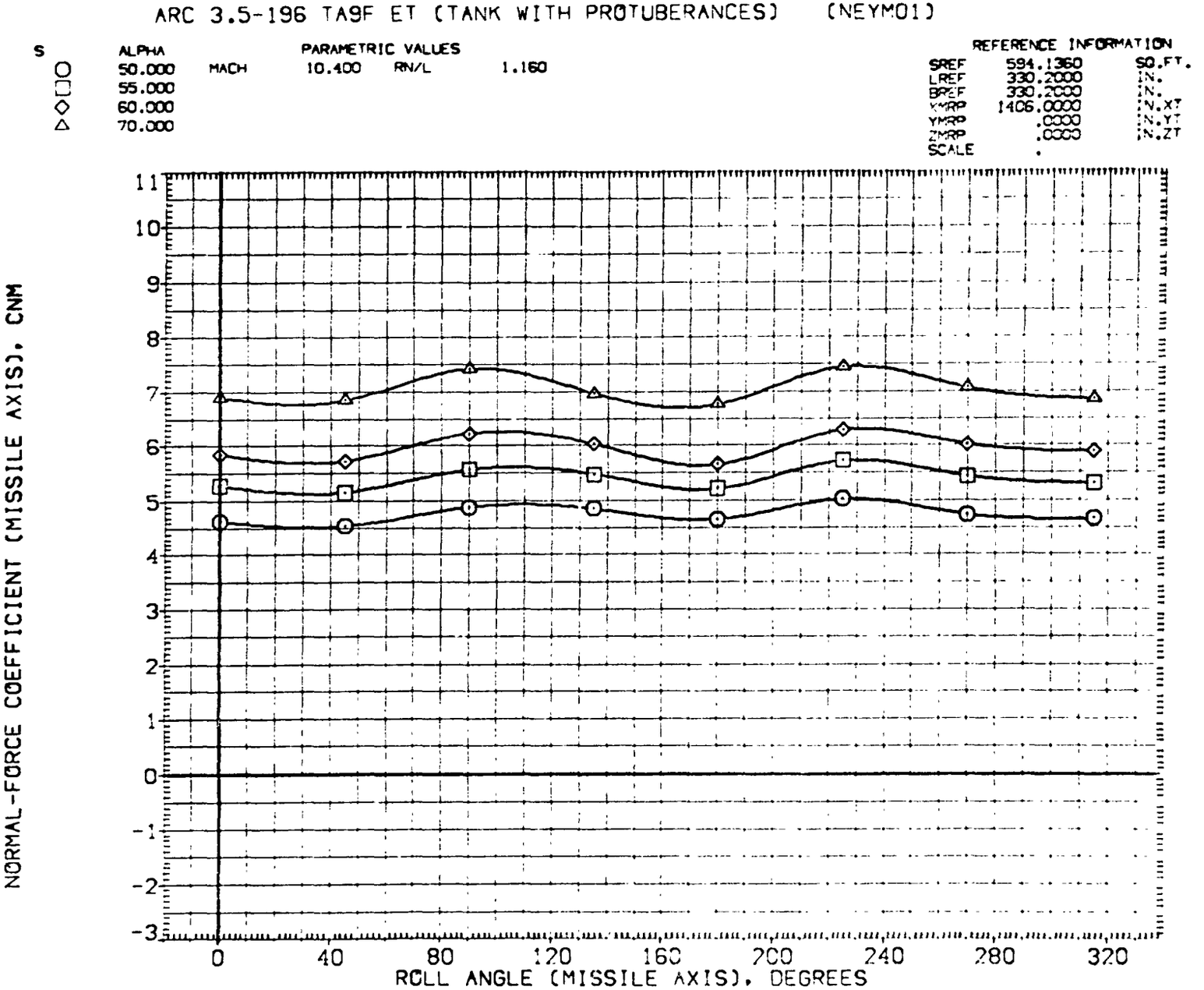


FIG. 9 COEFFICIENTS VERSUS ANGLE OF ROLL

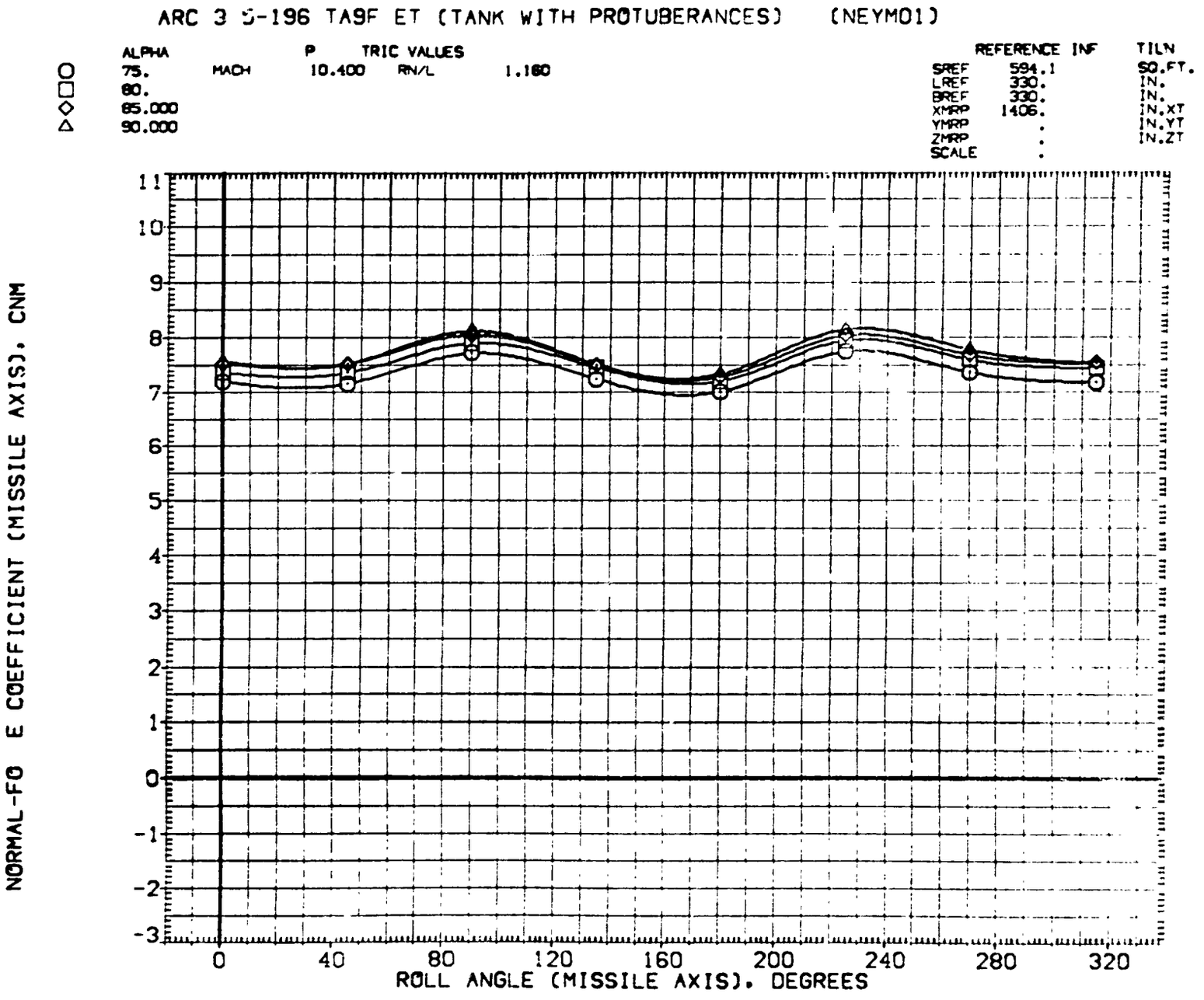


FIG. 9 COEFFICIENTS VERSUS ANGLE OF ROLL

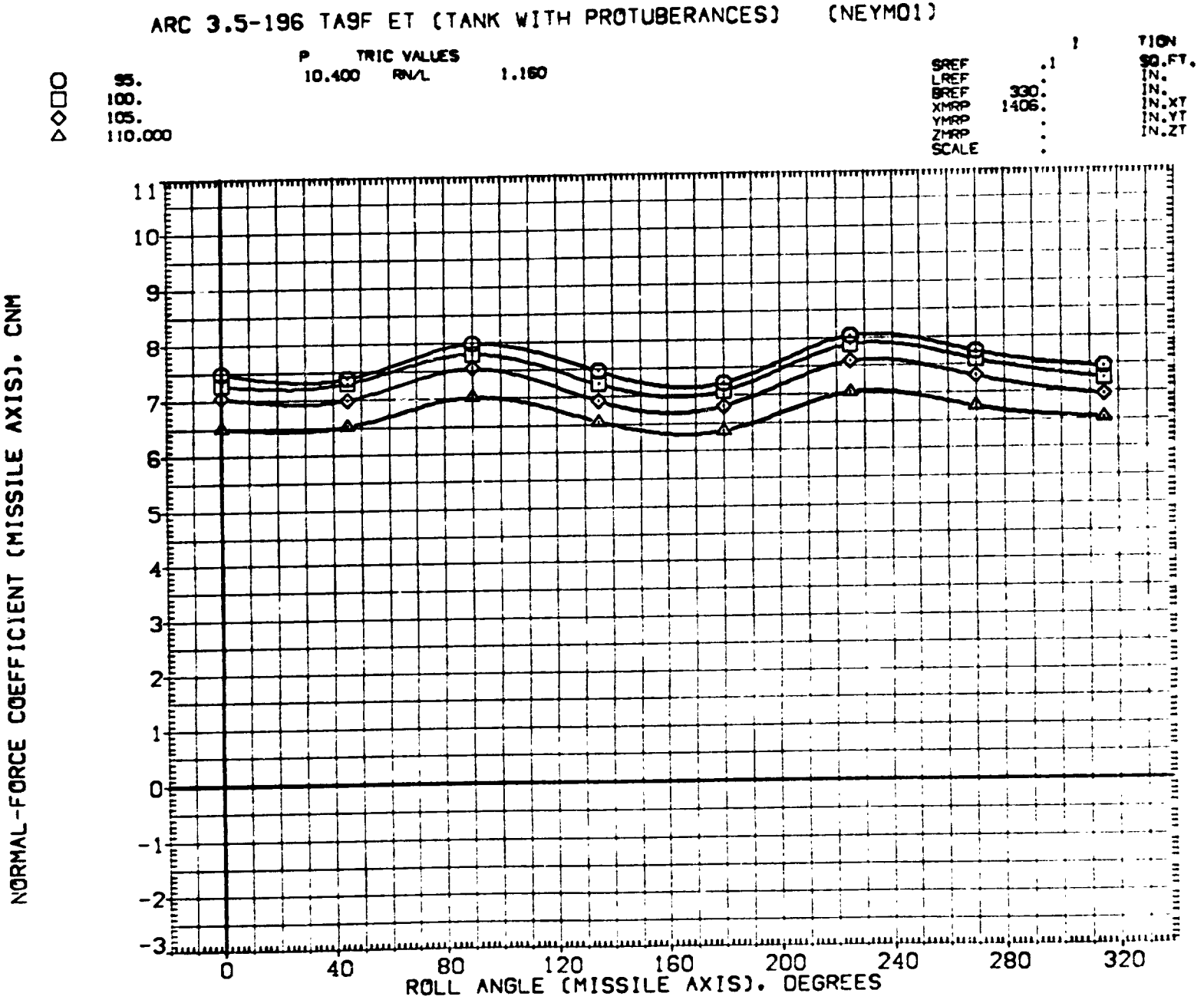


FIG. 9 COEFFICIENTS VERSUS ANGLE OF ROLL

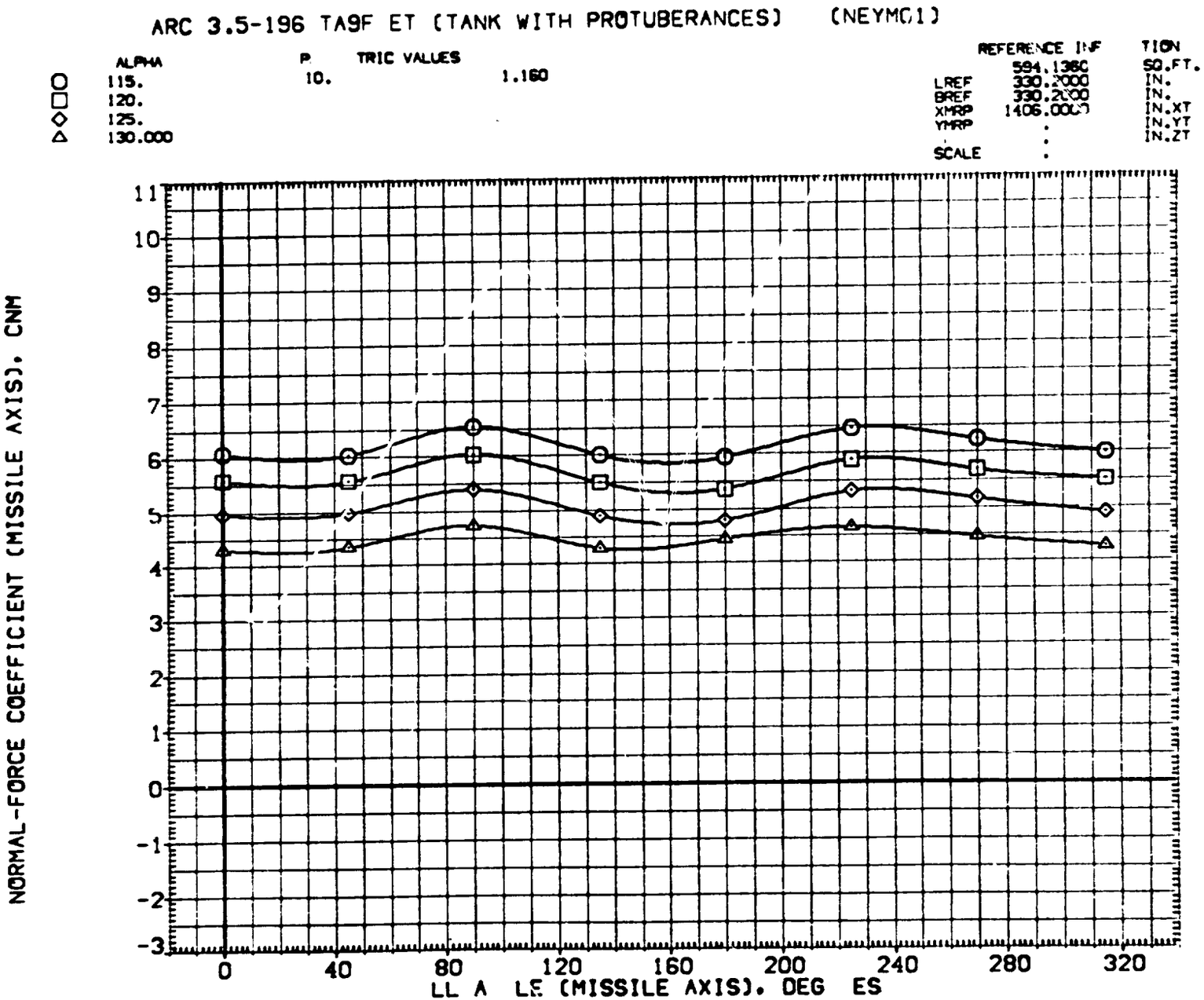
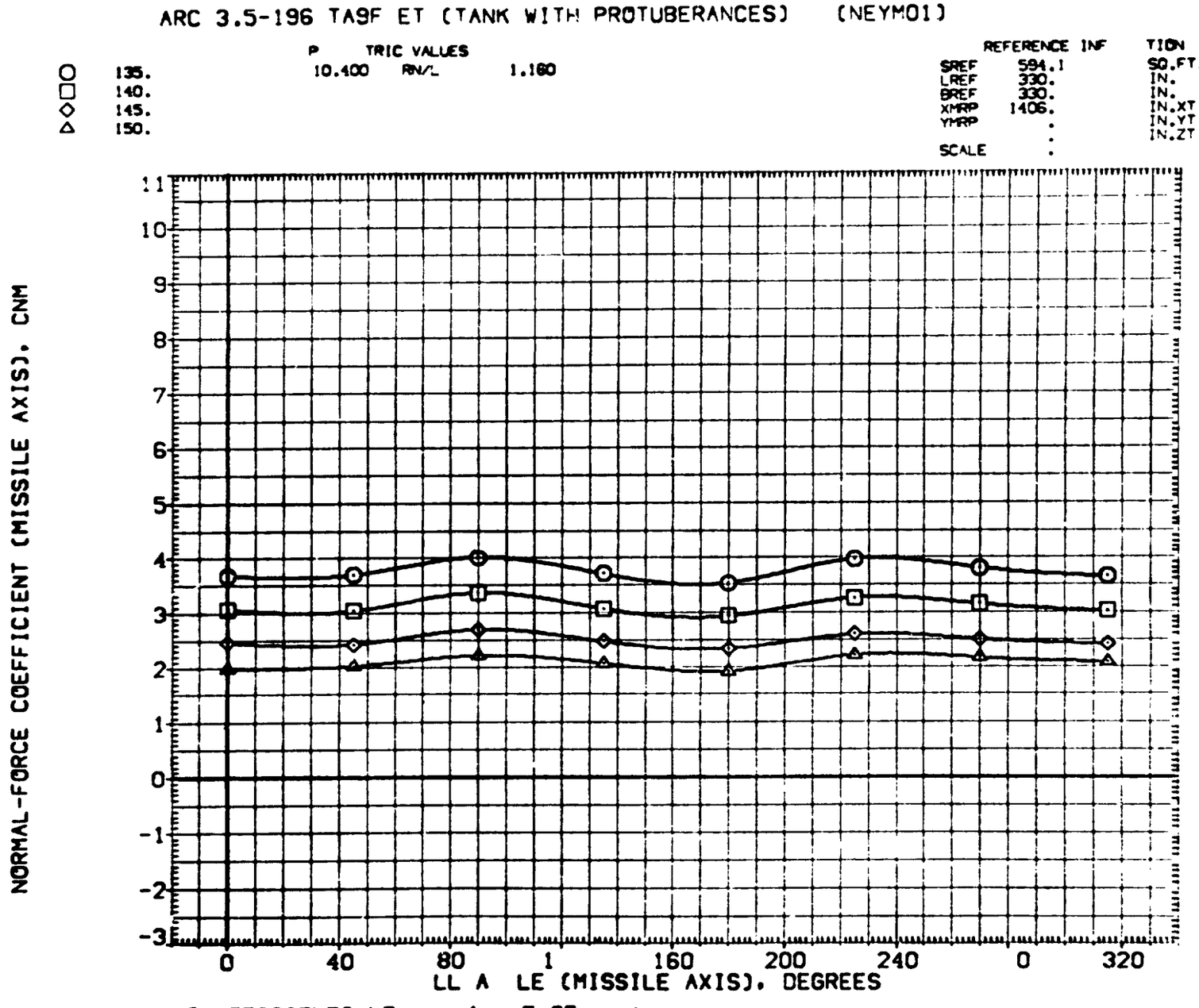


FIG. 9 COEFFICIENTS VE ANGLE OF L



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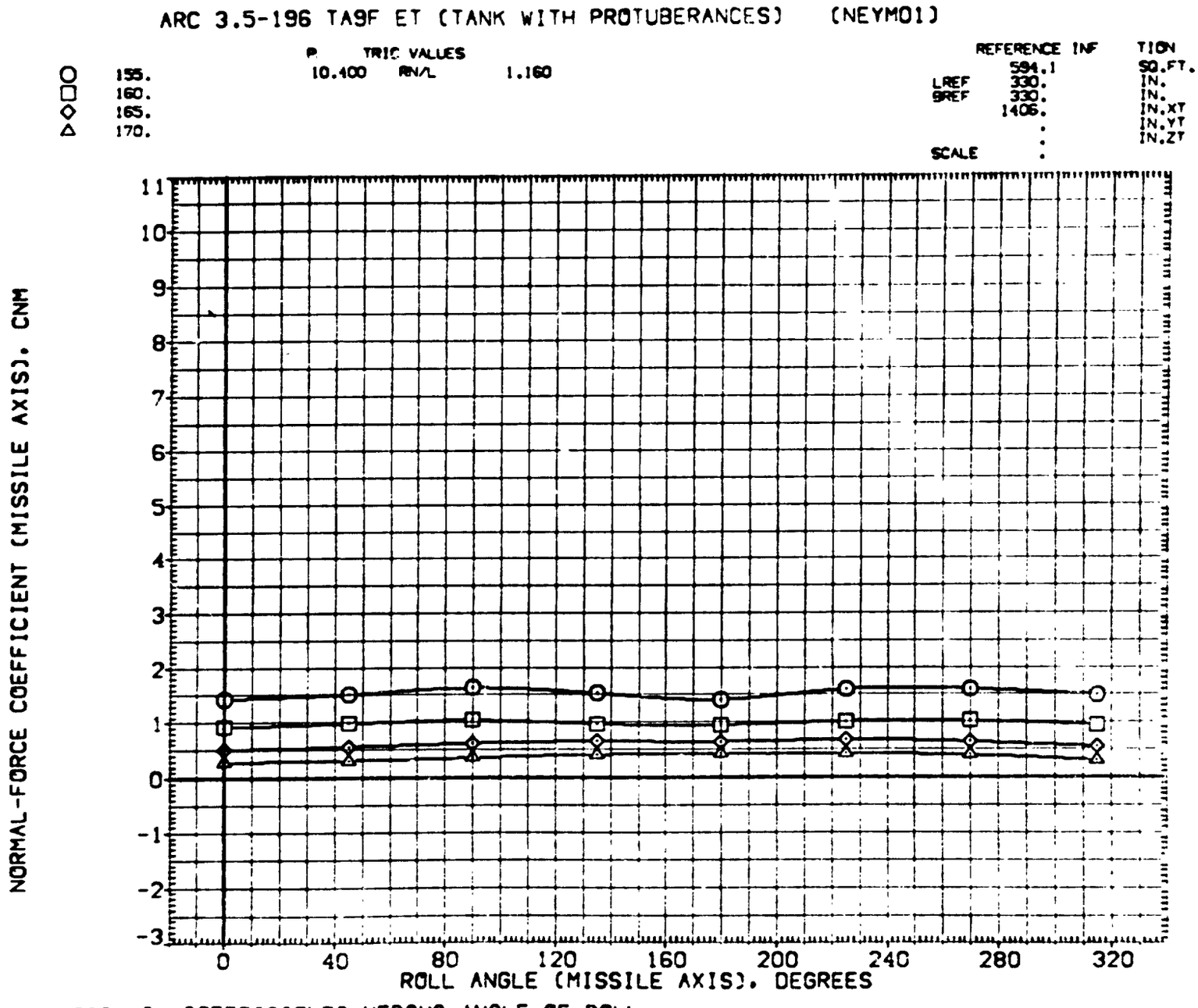

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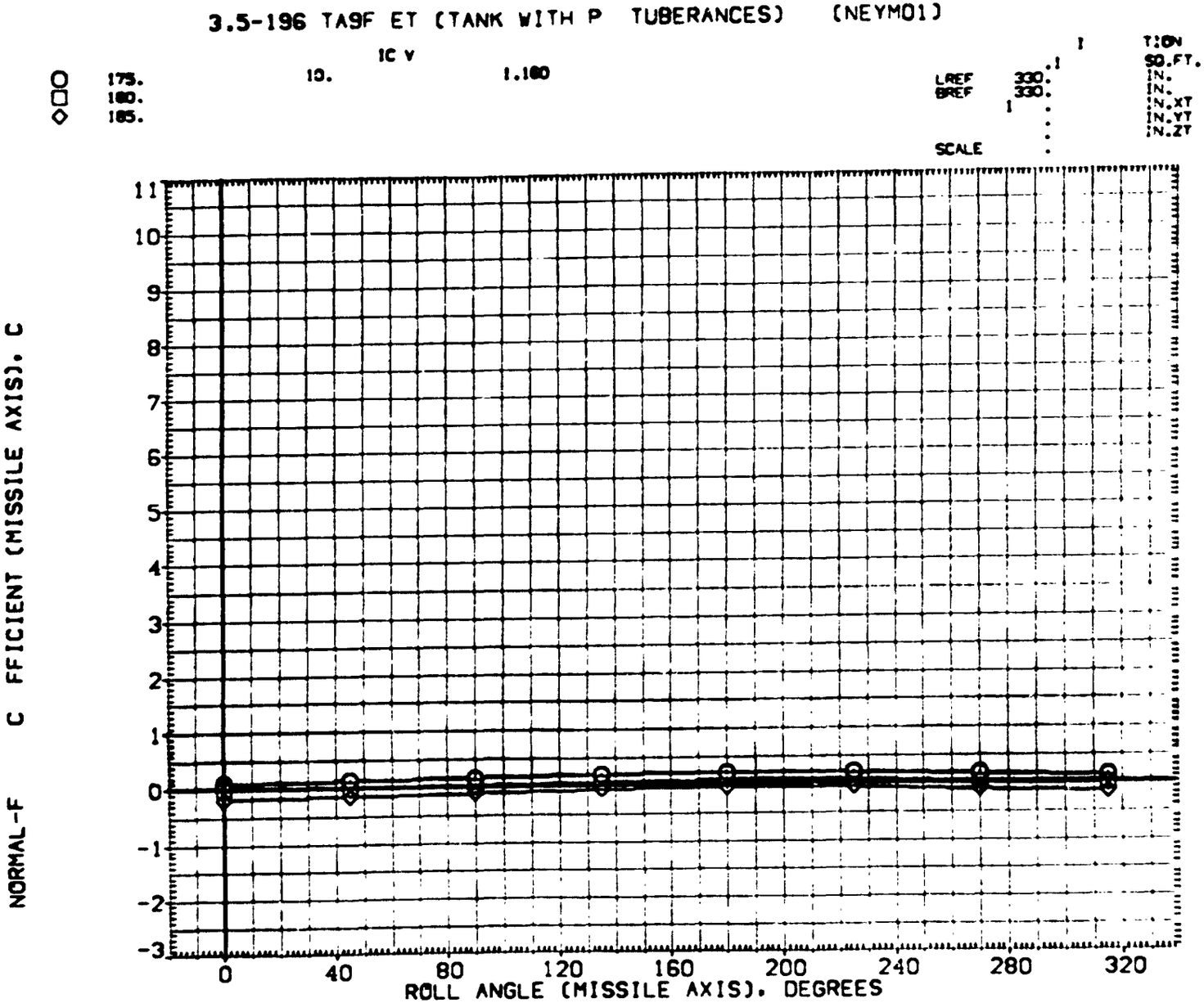

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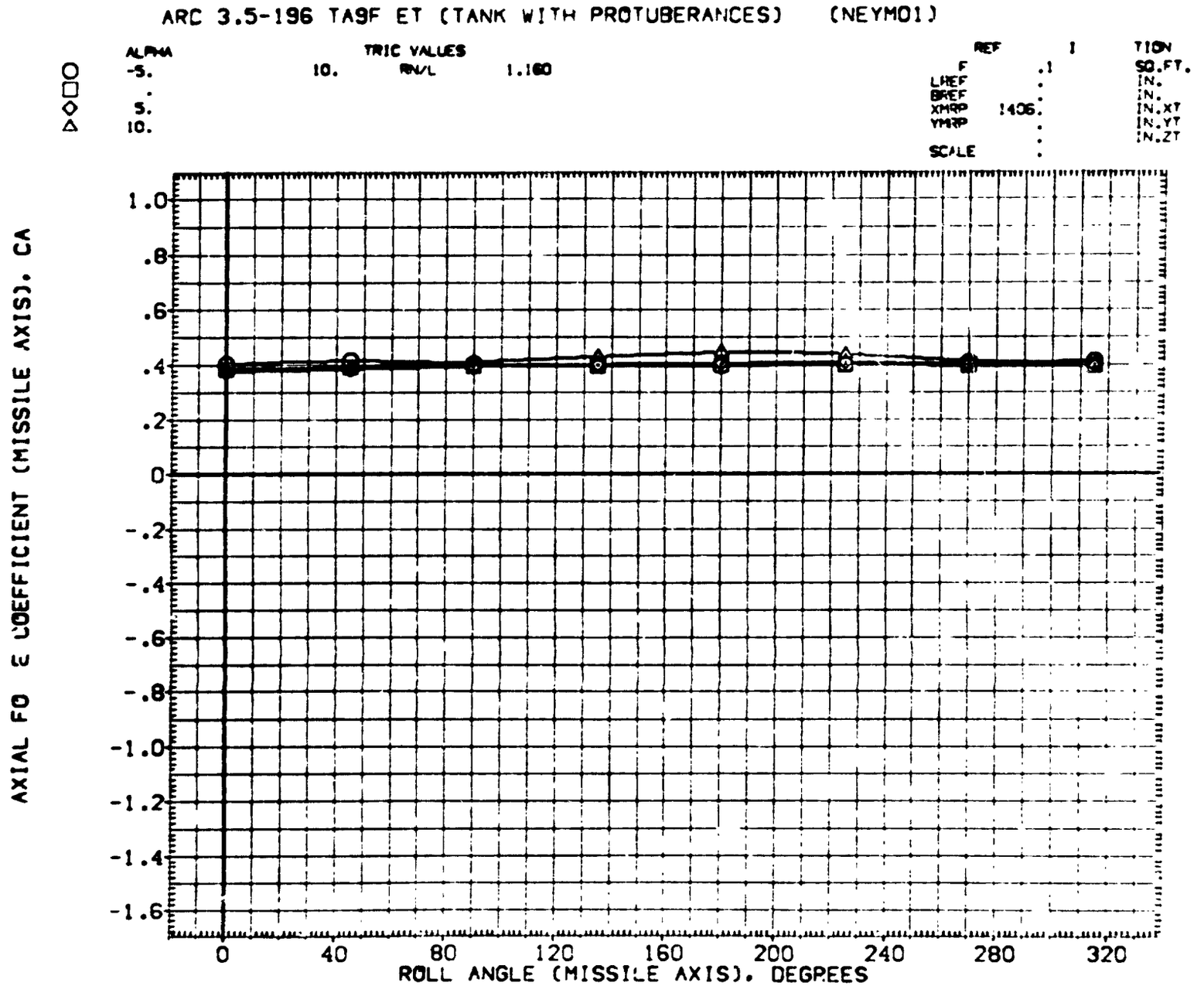


FIG. 9 COEFFICIENTS VE US ANGLE OF ROLL

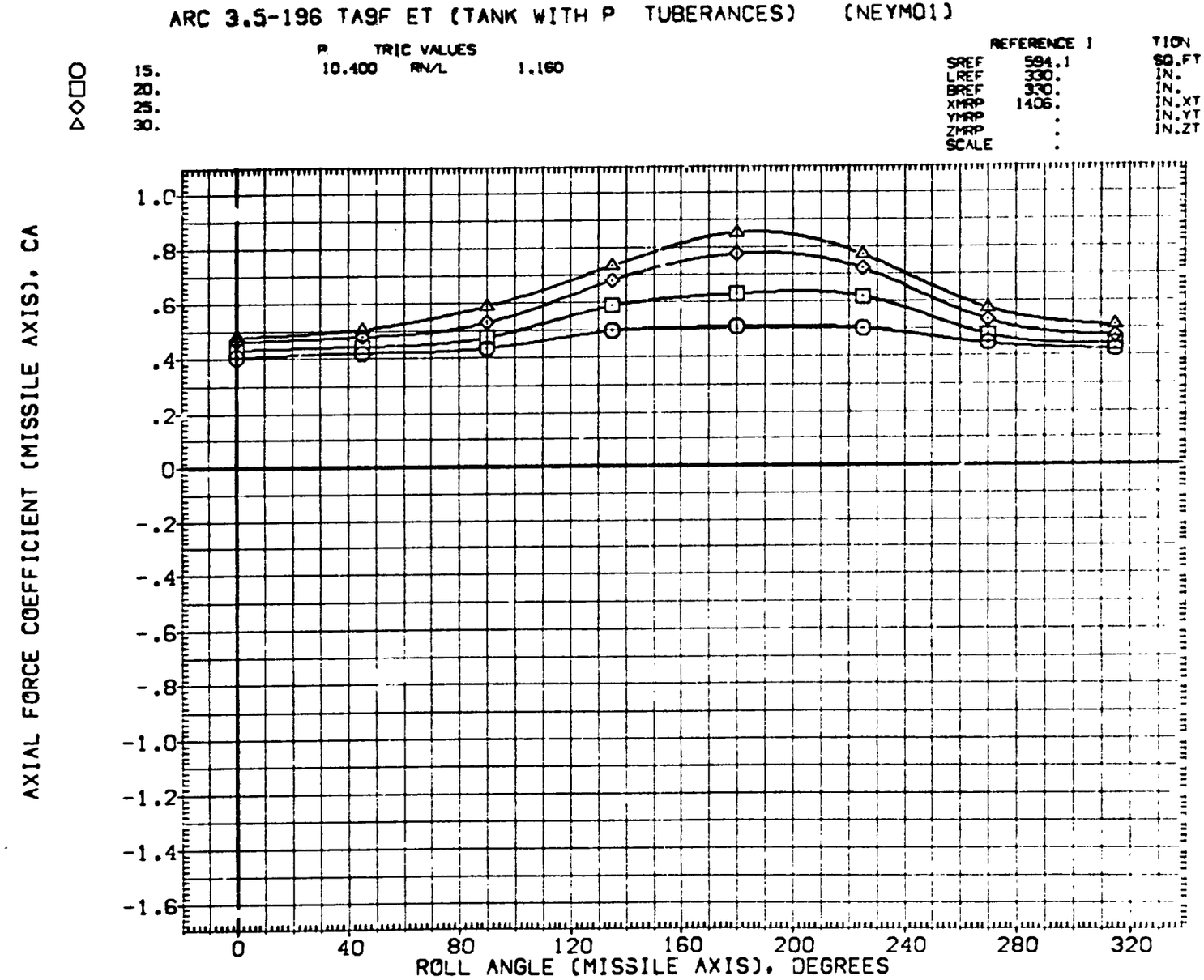


FIG. 9 COEFFICIENTS VERSUS ANGLE OF ROLL

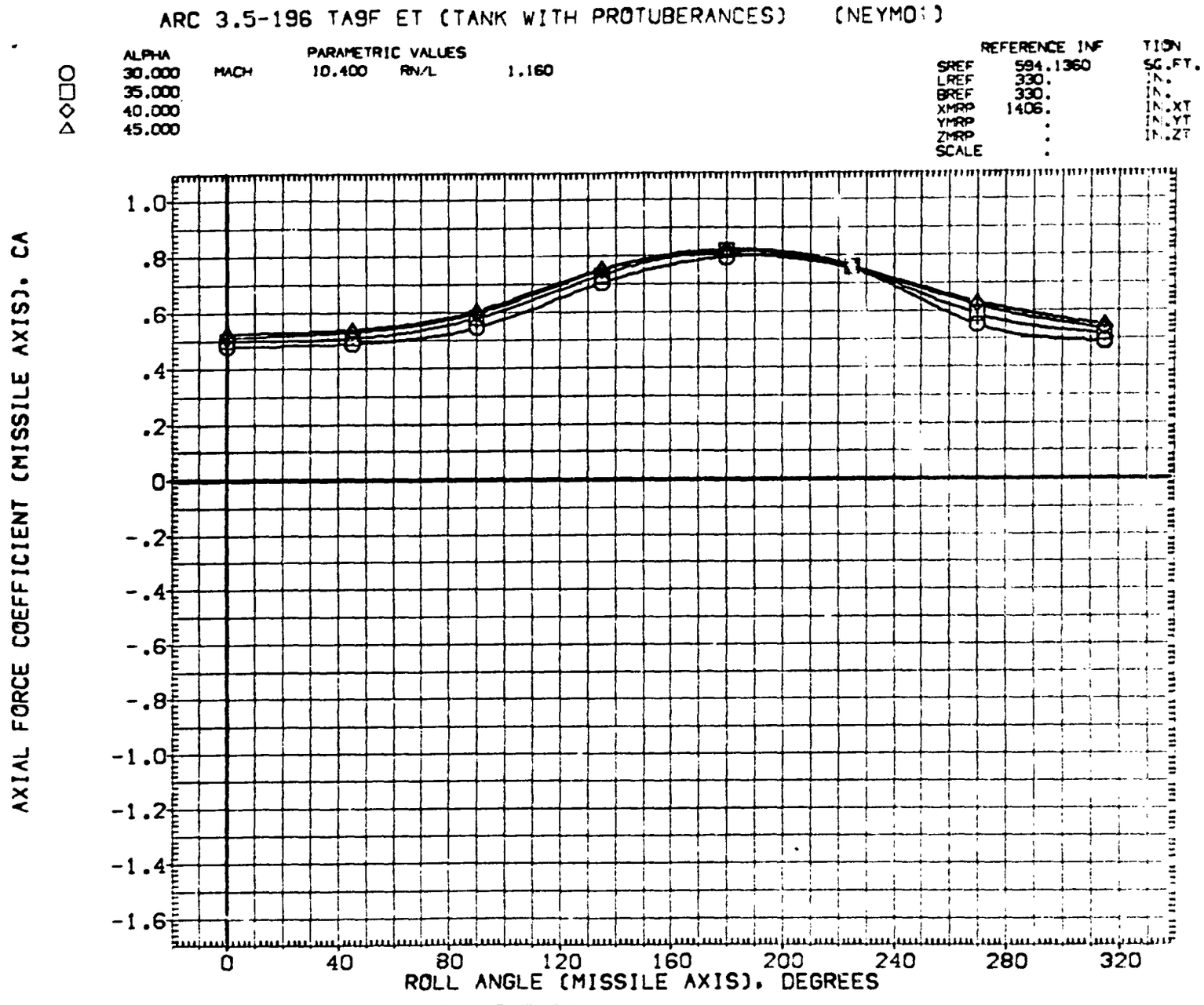


FIG. 9 COEFFICIENTS VERSUS ANGLE OF ROLL

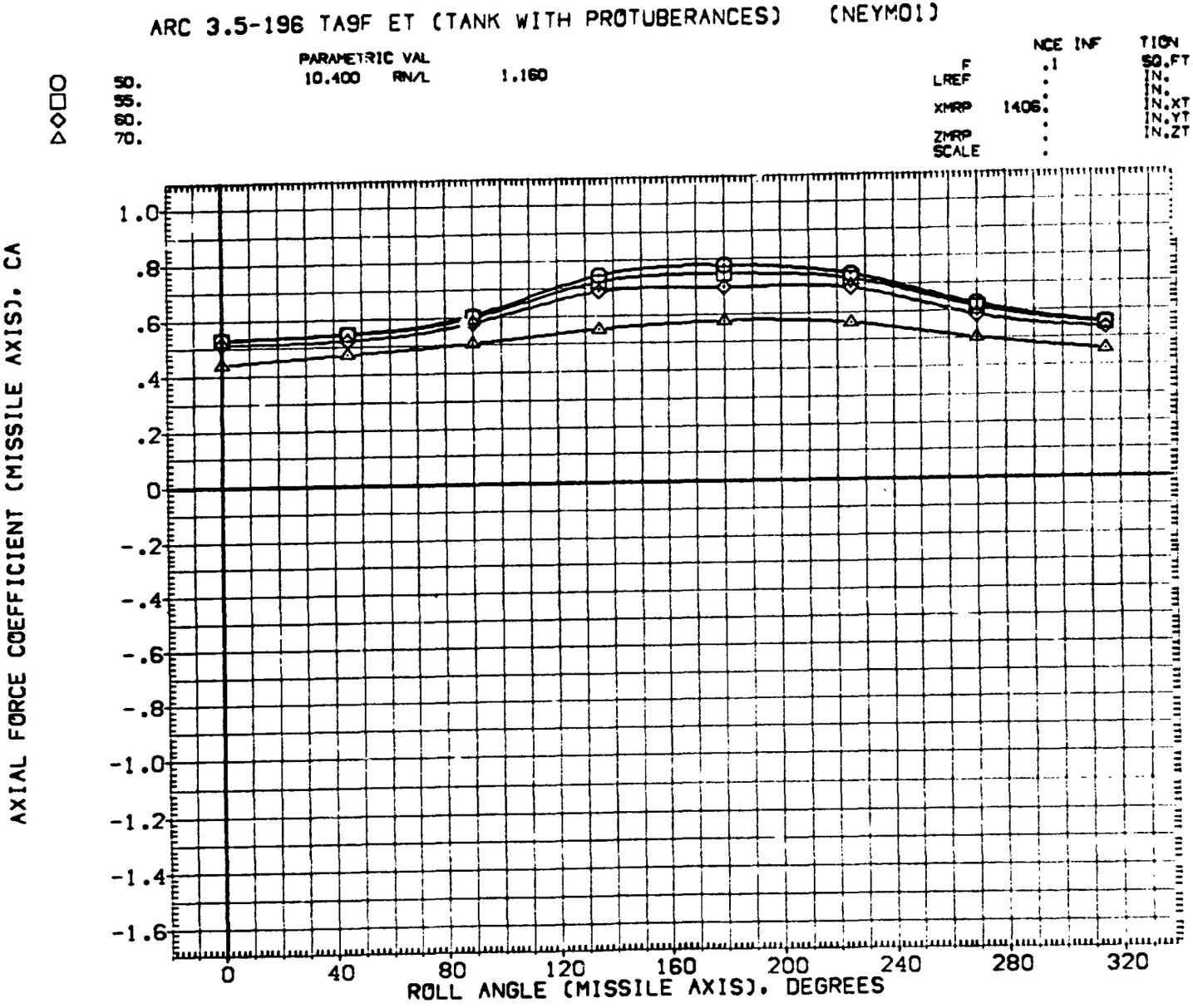
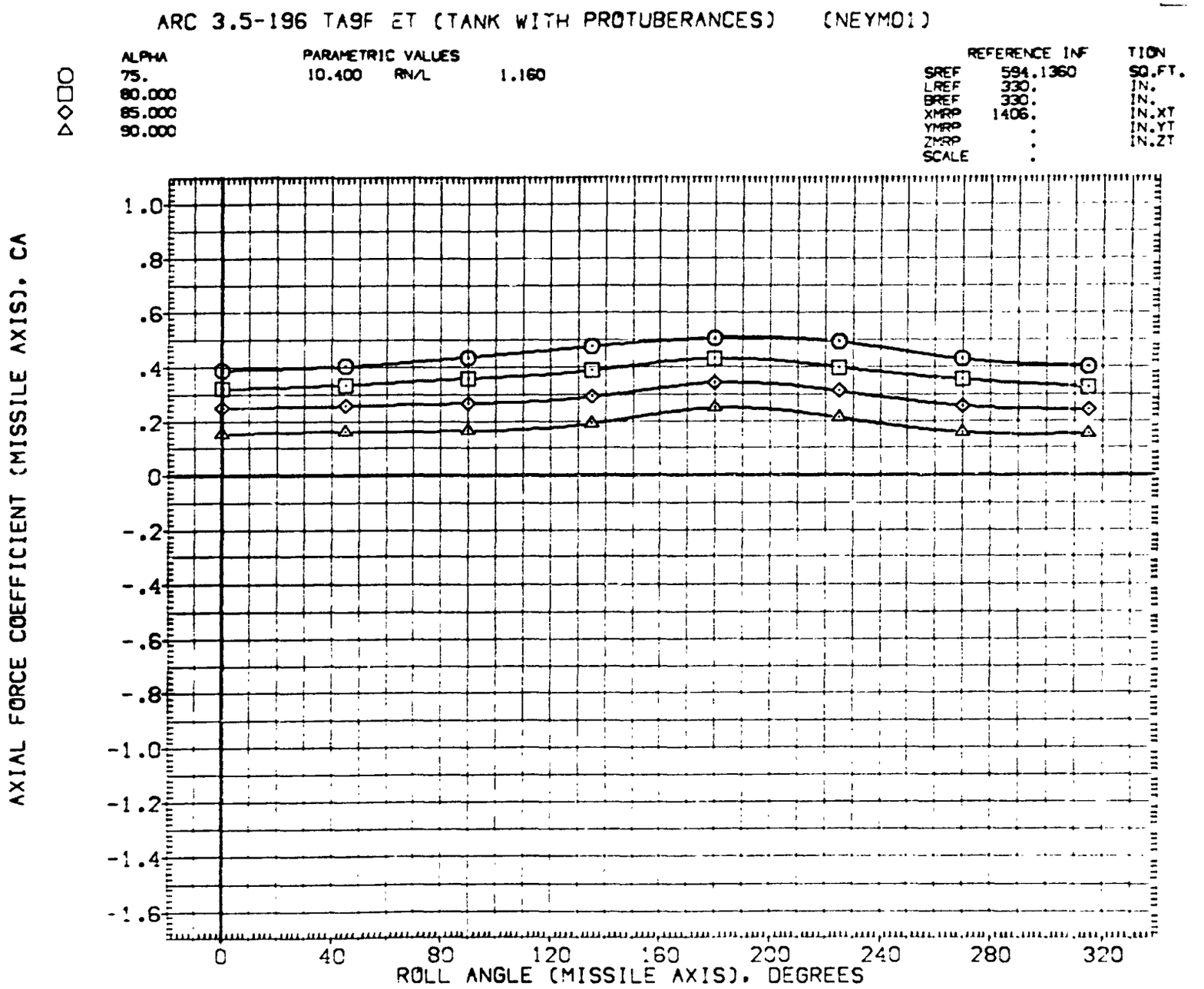


FIG. 9 COEFFICIENTS VERSUS ANGLE OF ROLL



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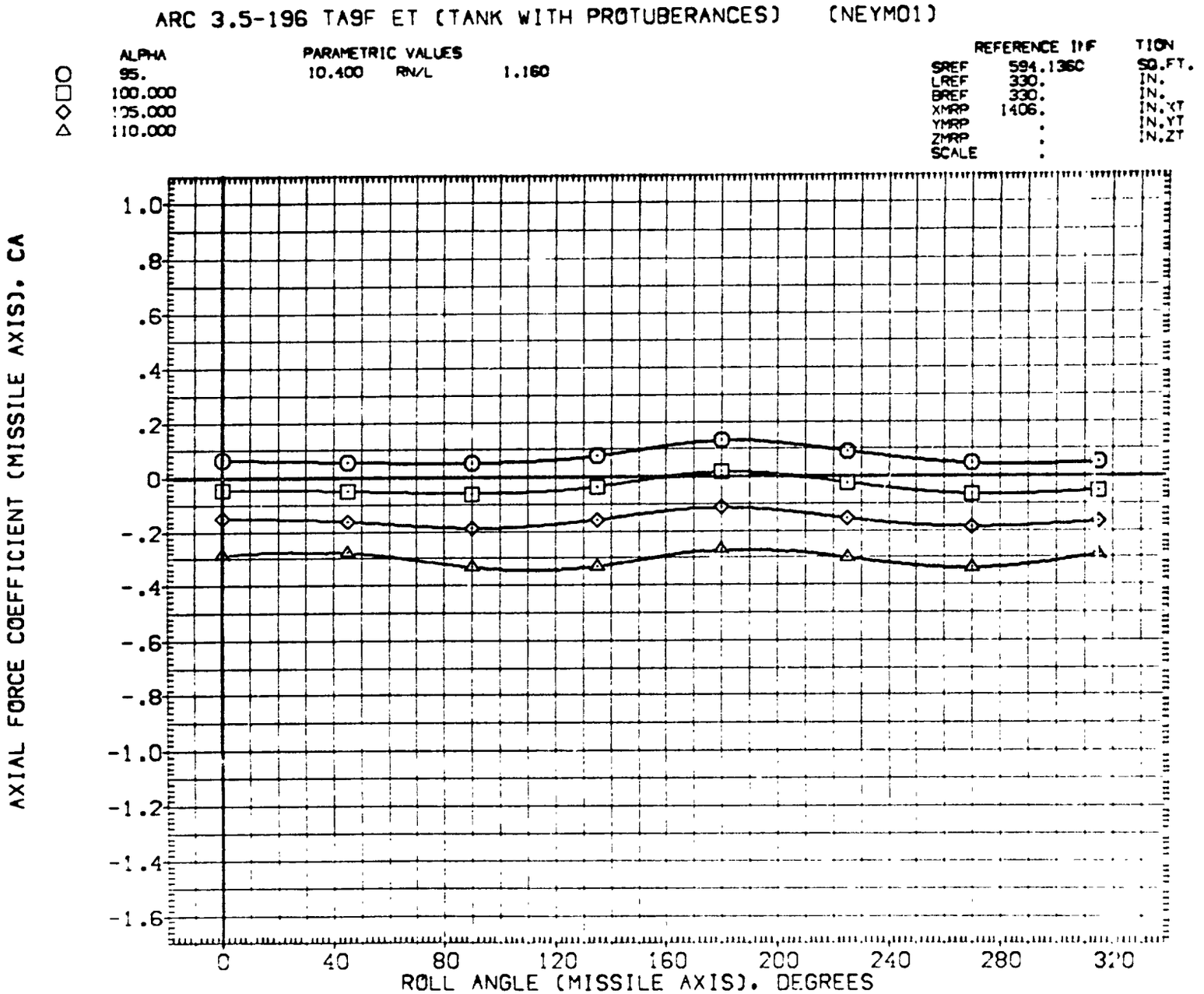

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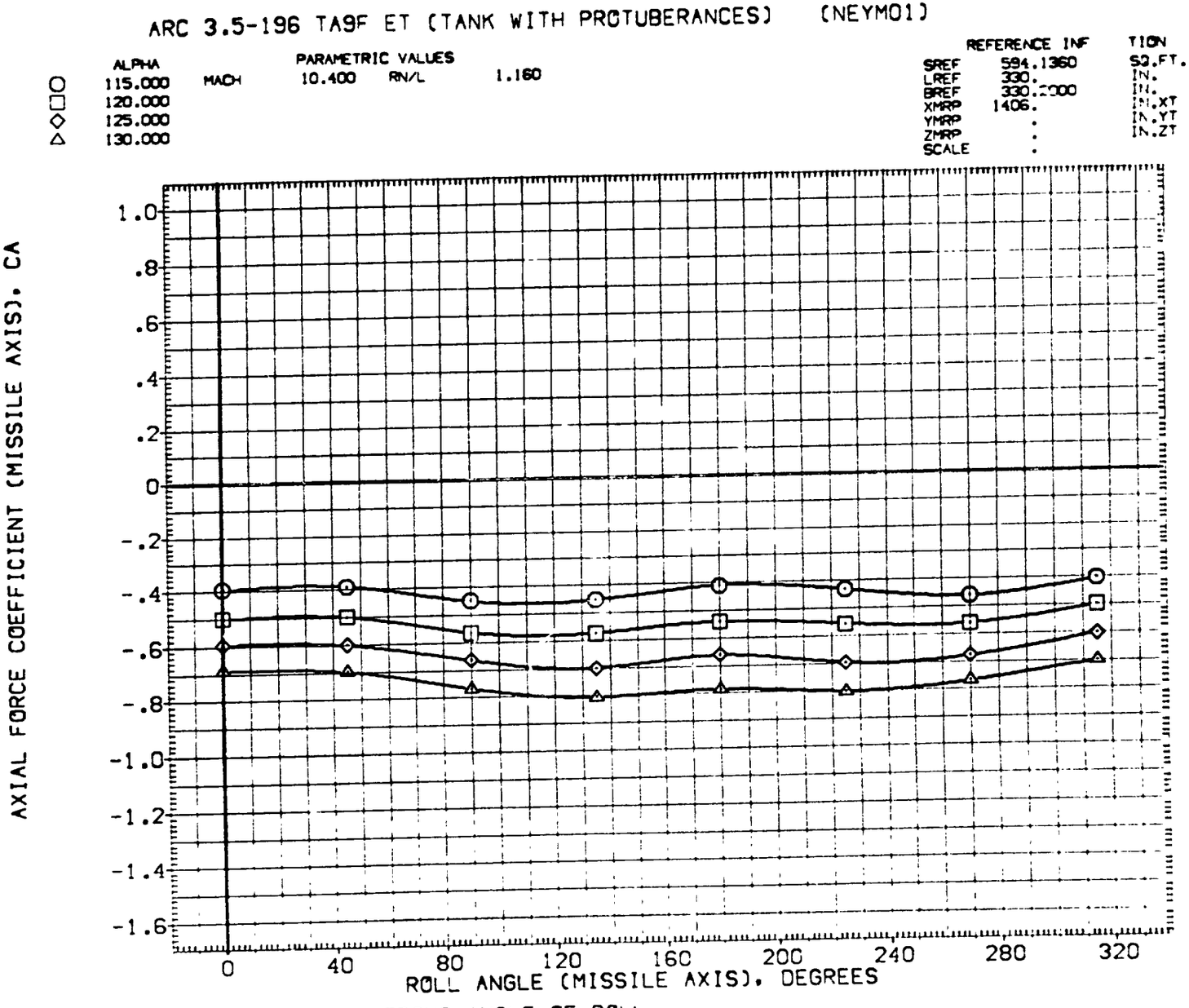

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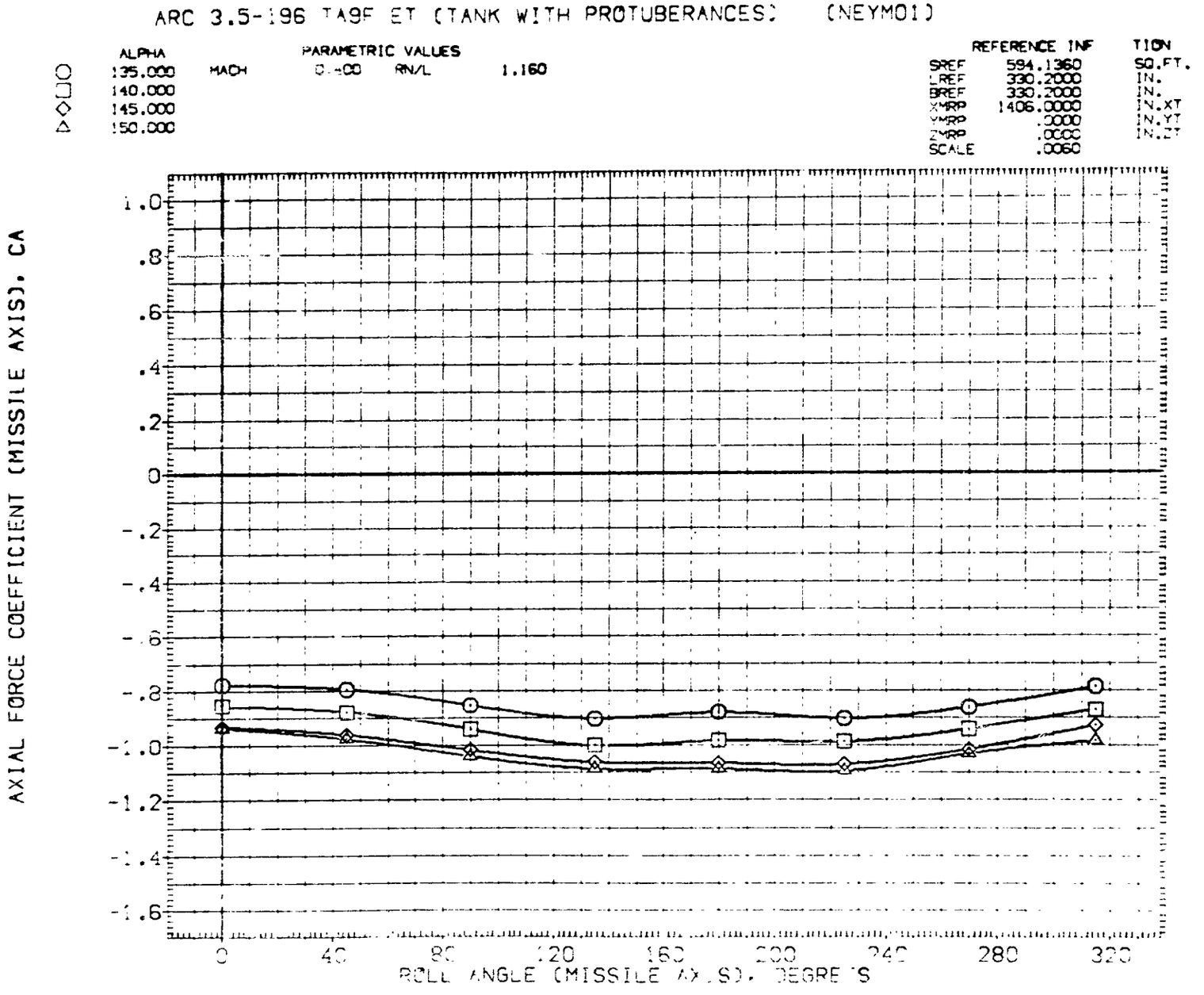


FIG. 9 COEFFICIENTS VERSUS ANGLE OF ROLL

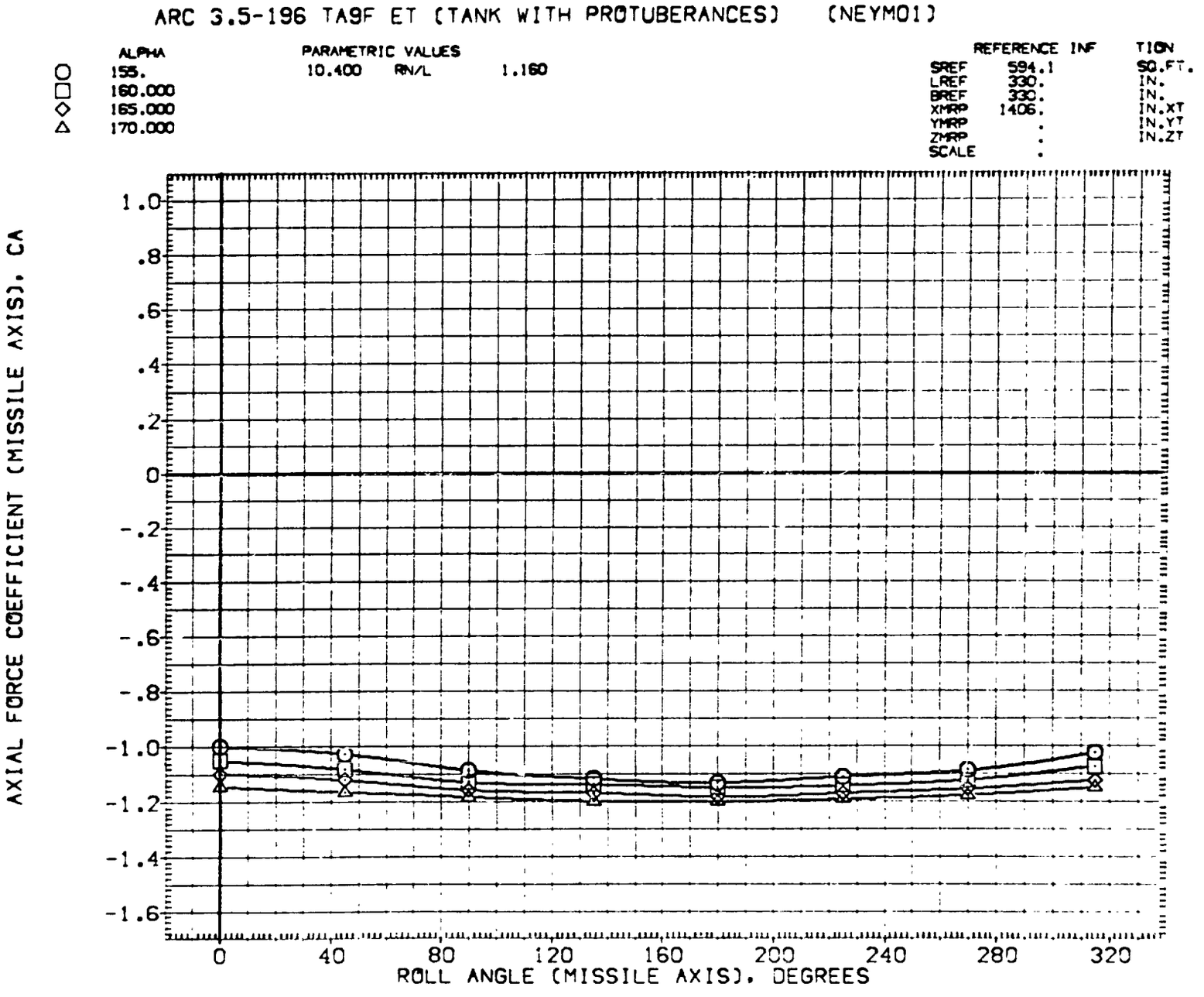
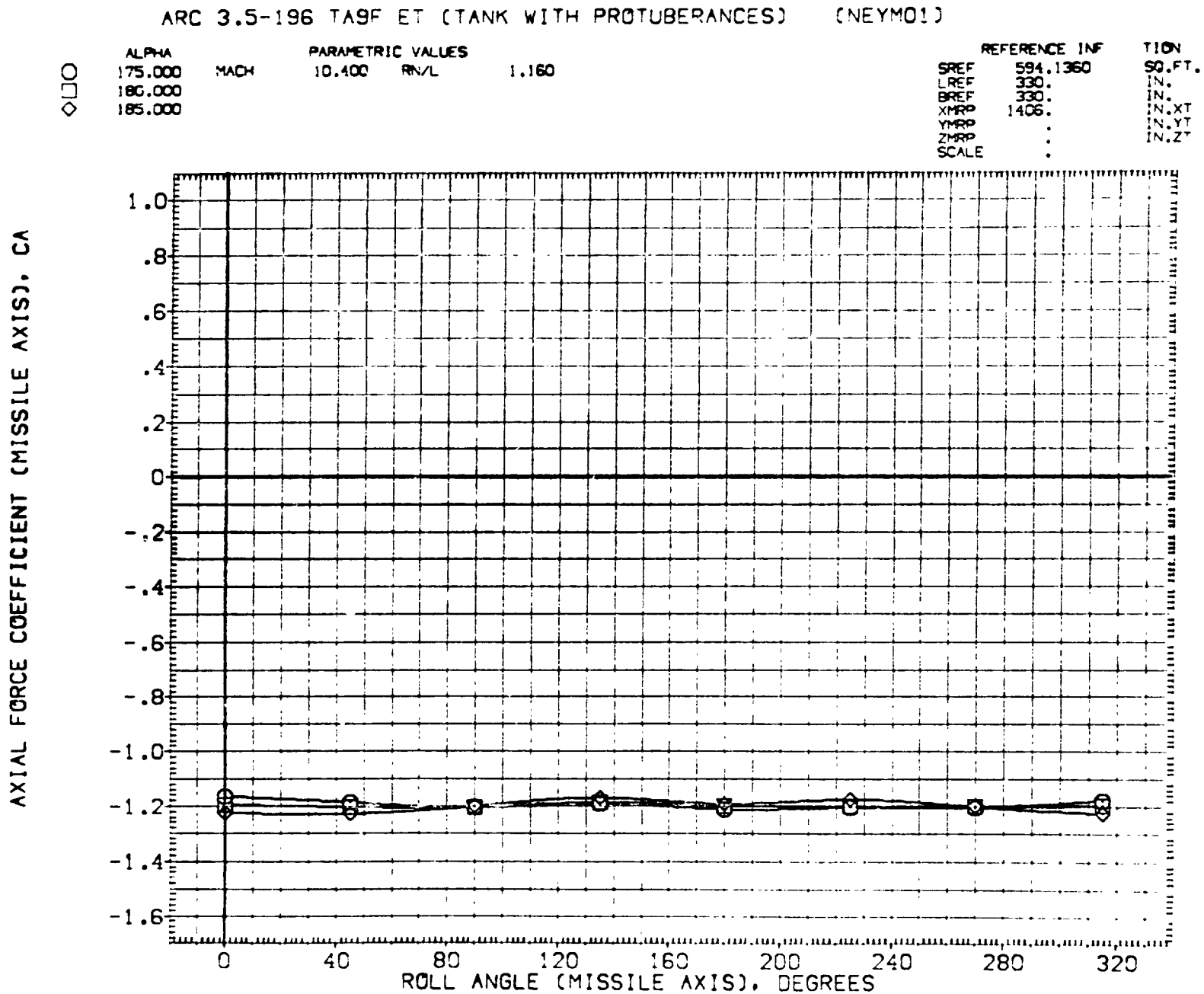


FIG. 9 COEFFICIENTS VERSUS ANGLE OF ROLL



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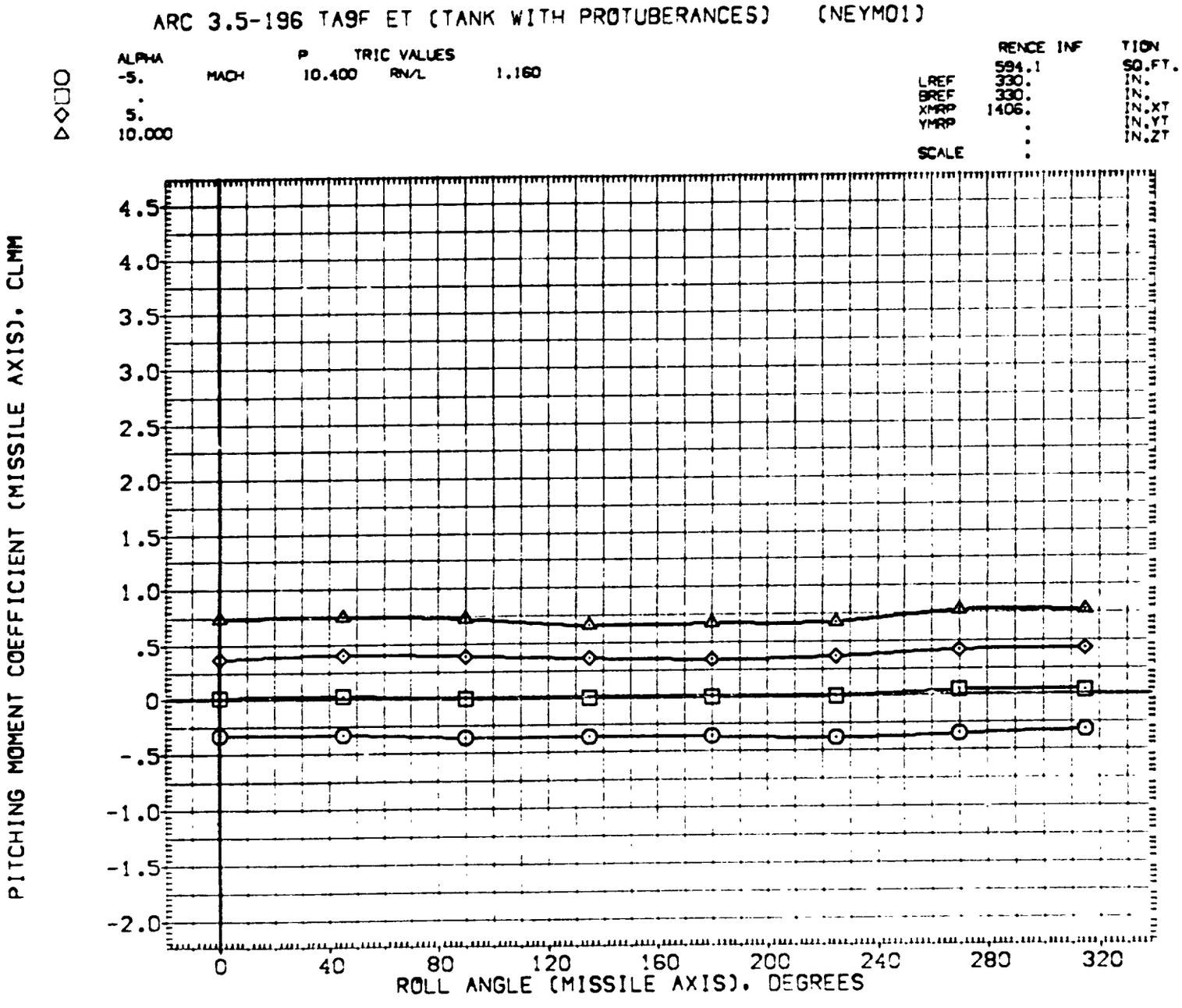

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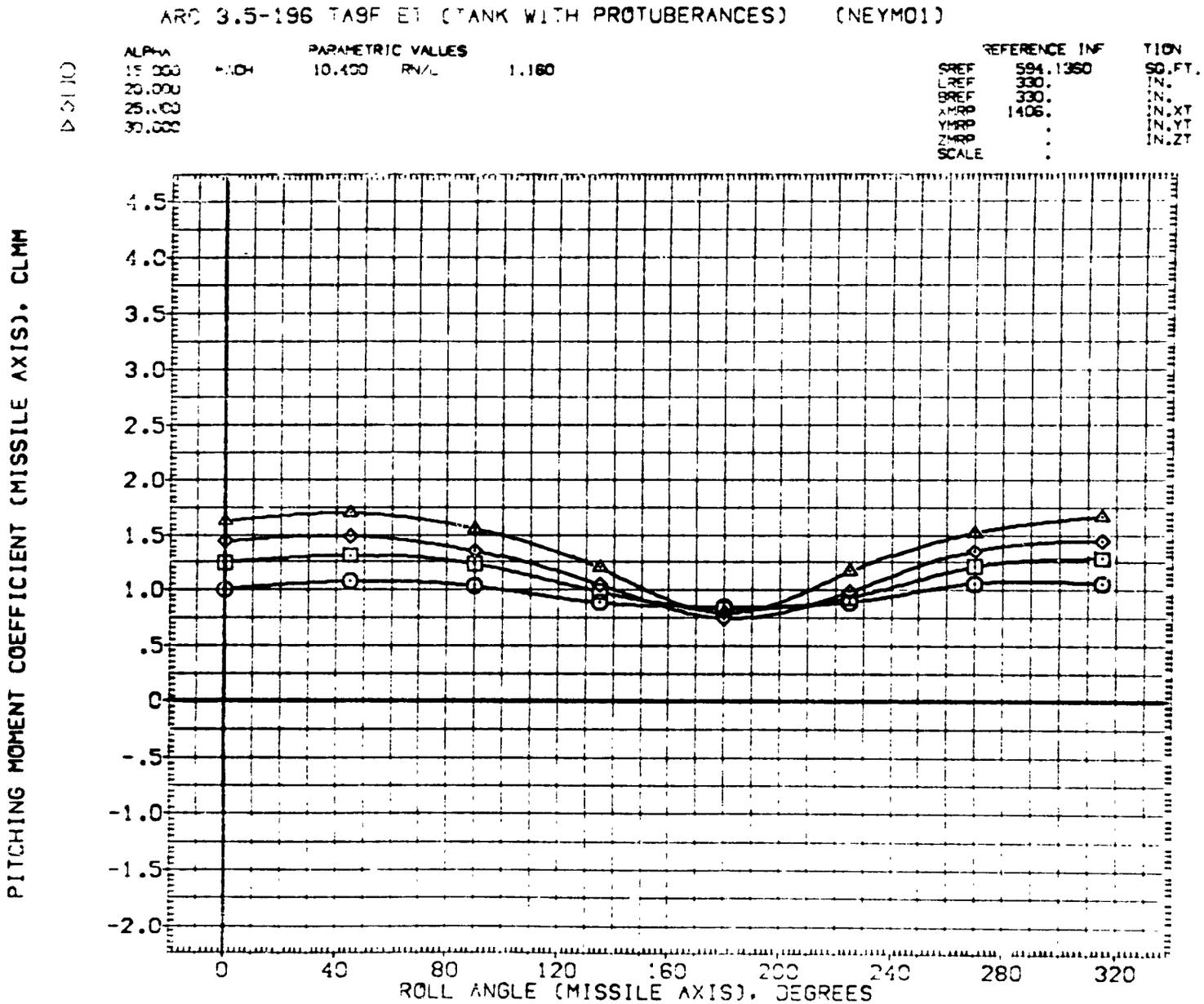

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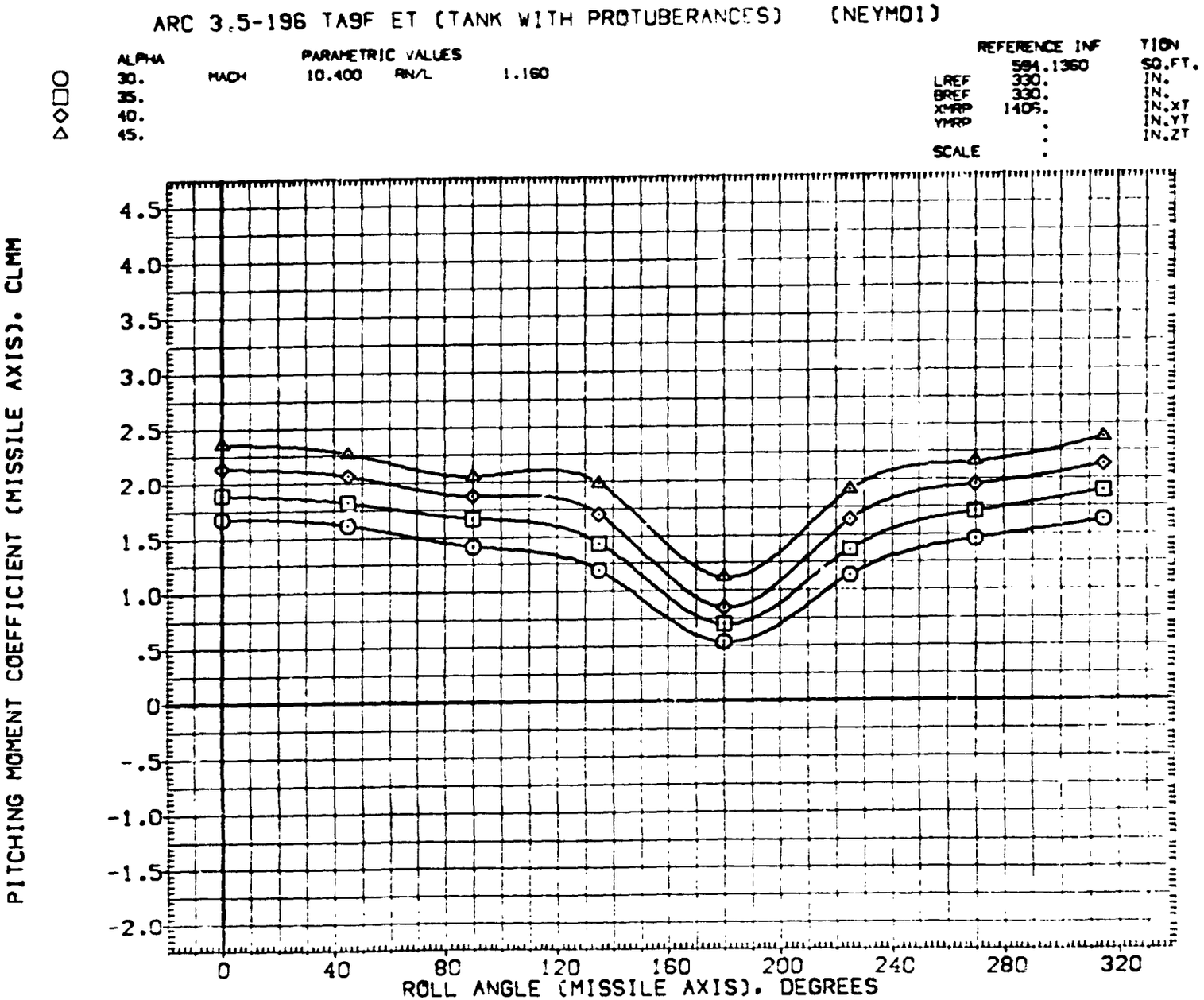


FIG. 9 COEFFICIENTS VERSUS ANGLE OF ROLL

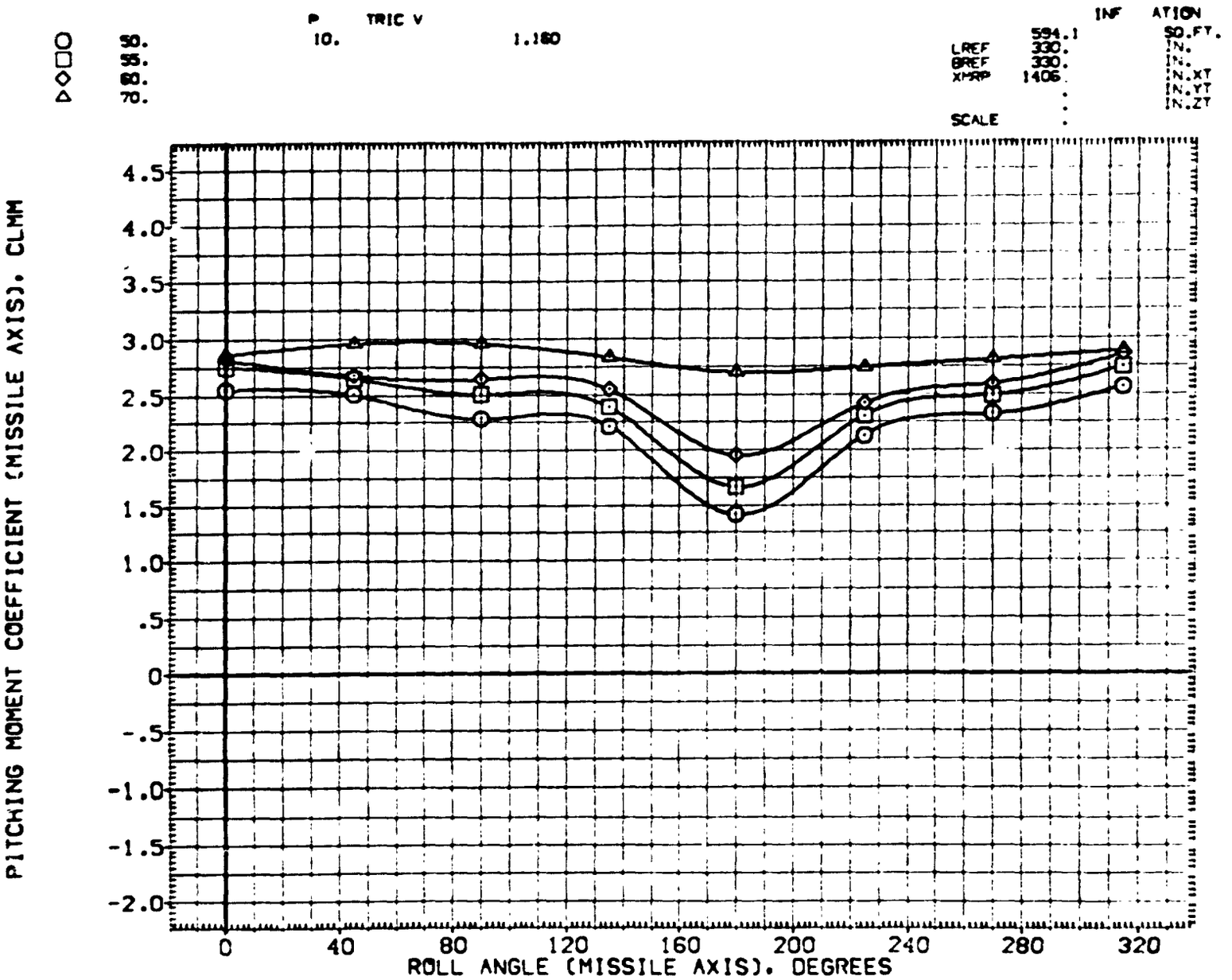


FIG. 9 COEFFICIENTS VERSUS ANGLE OF ROLL

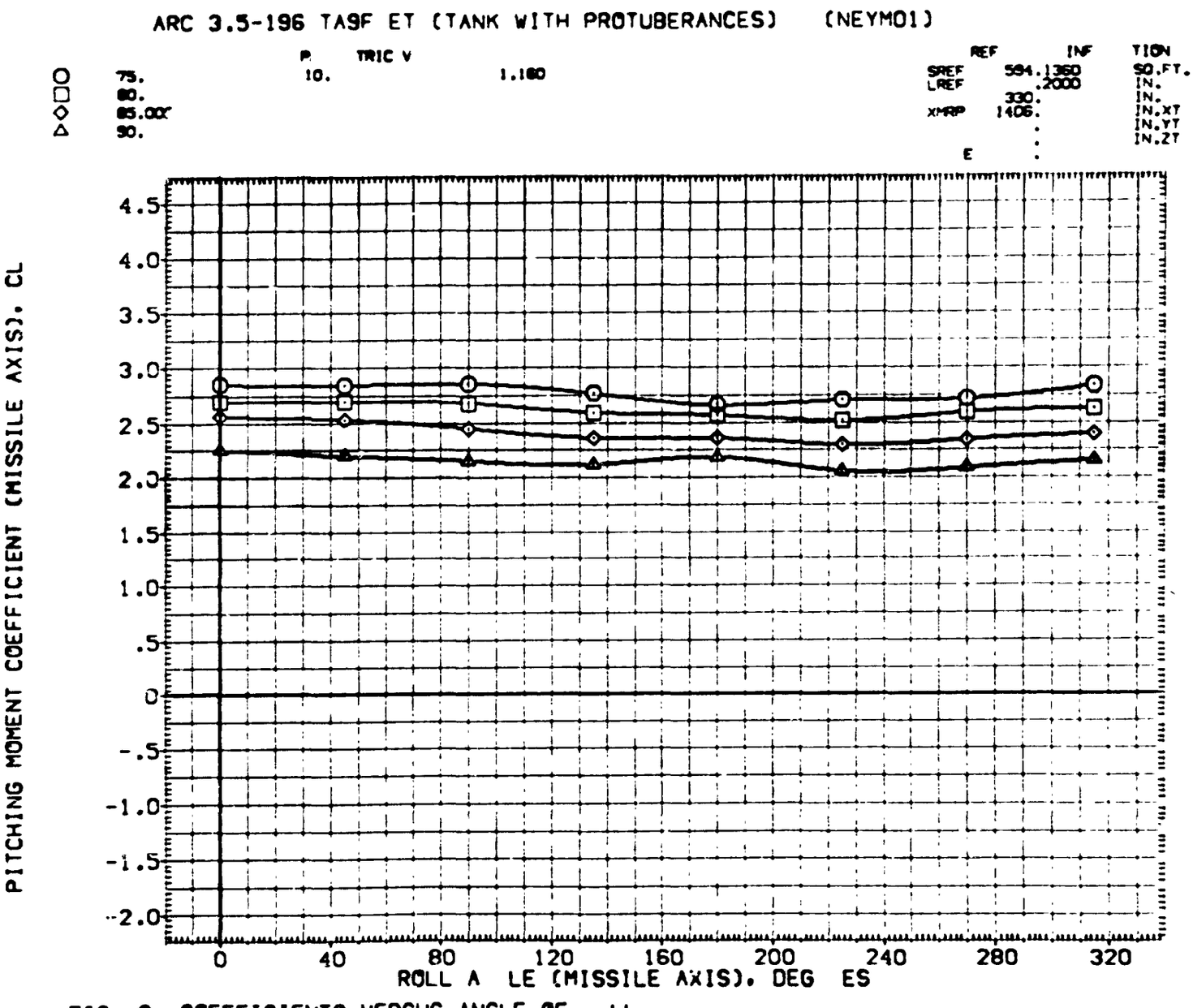


FIG. 9 COEFFICIENTS VERSUS ANGLE OF LL

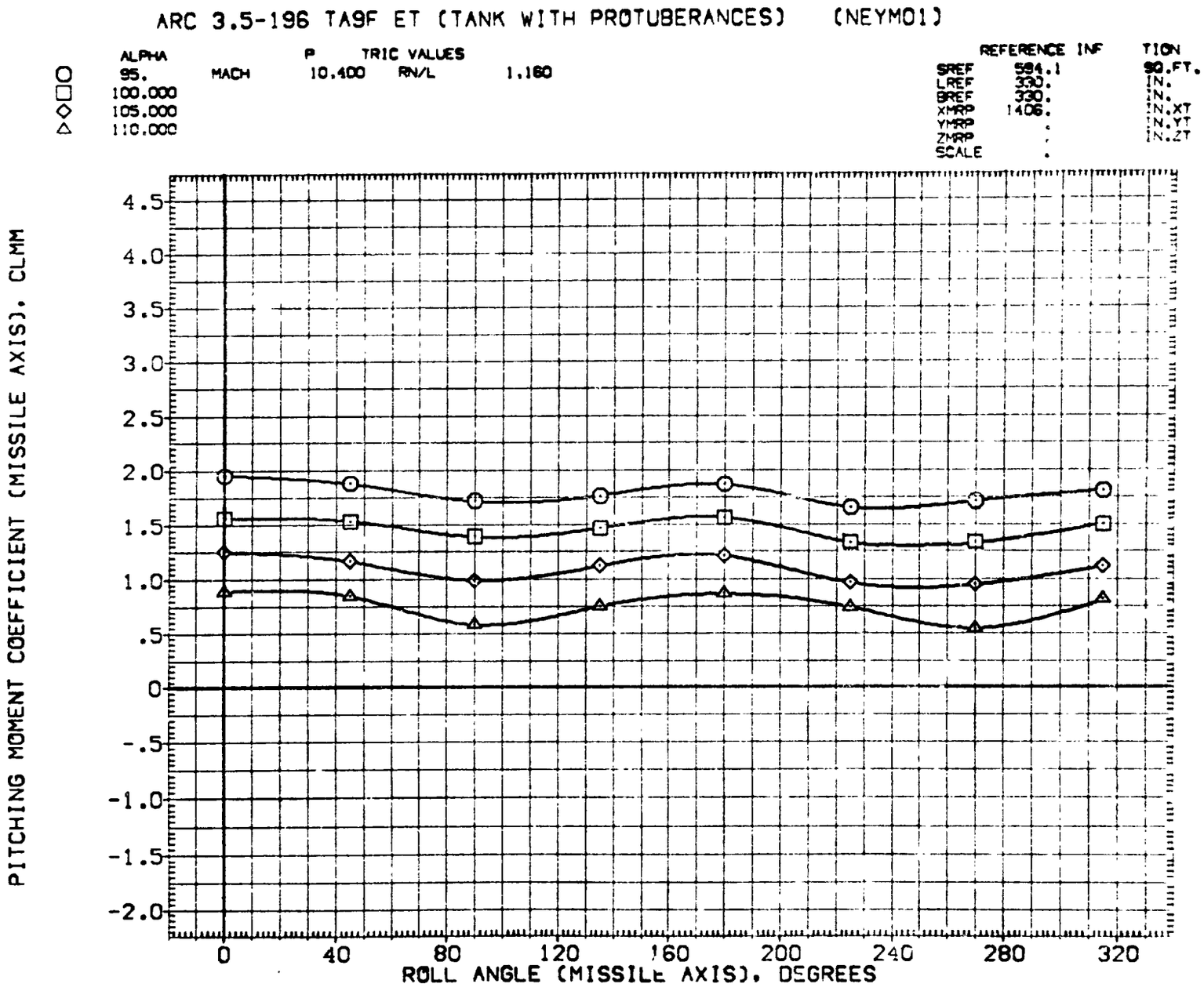


FIG. 9 COEFFICIENTS VERSUS ANGLE OF ROLL

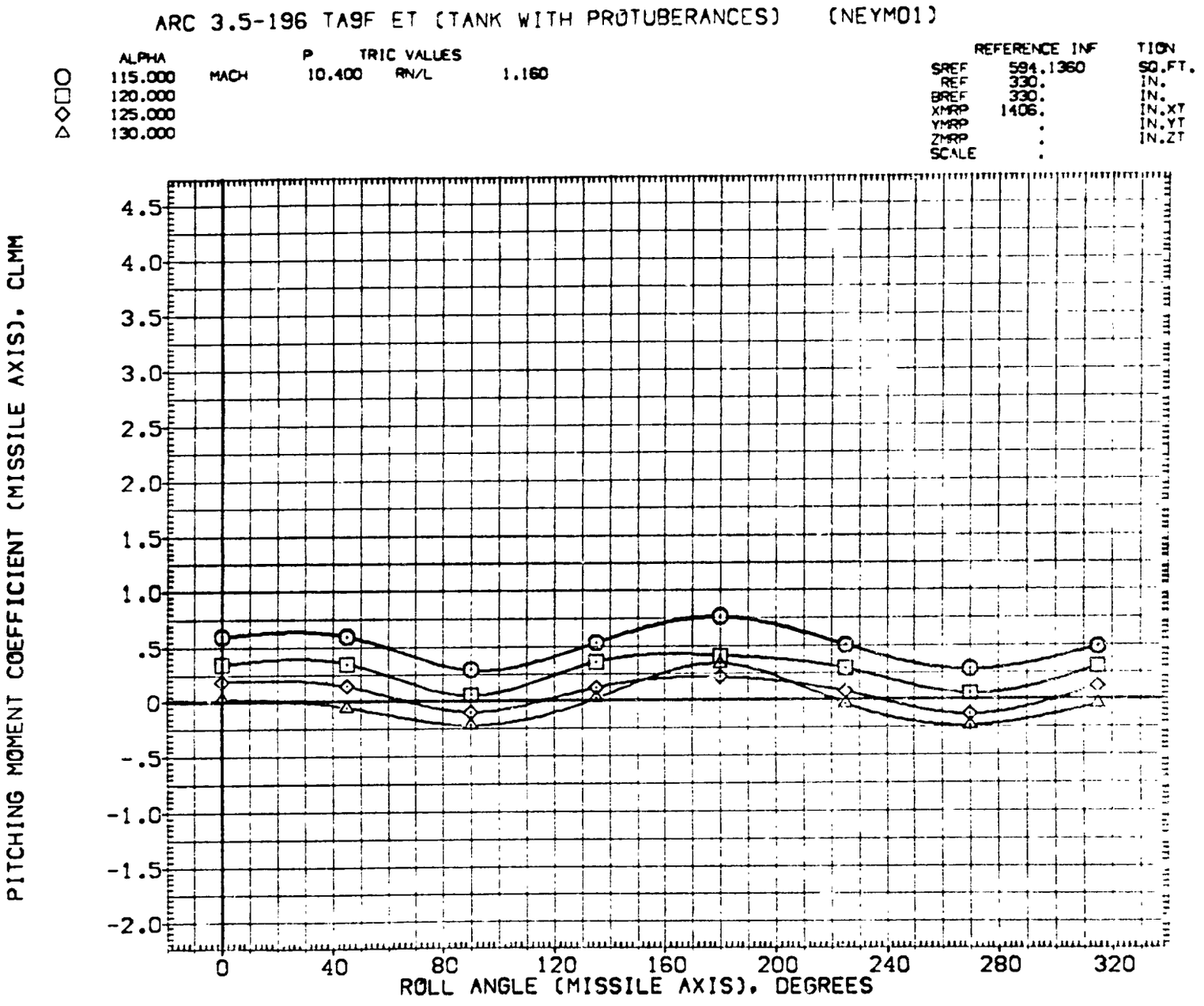


FIG. 9 COEFFICIENTS VERSUS ANGLE OF ROLL

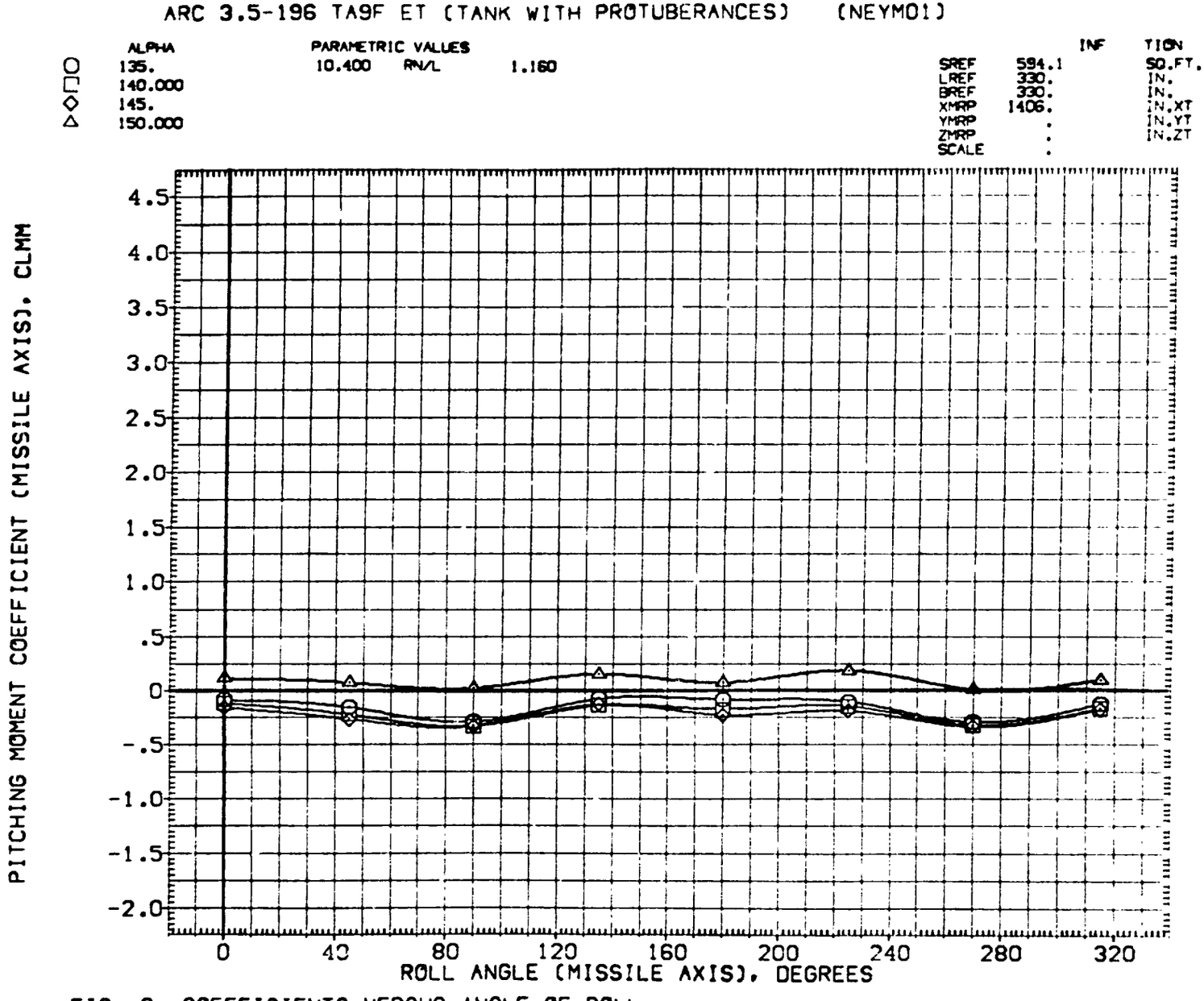
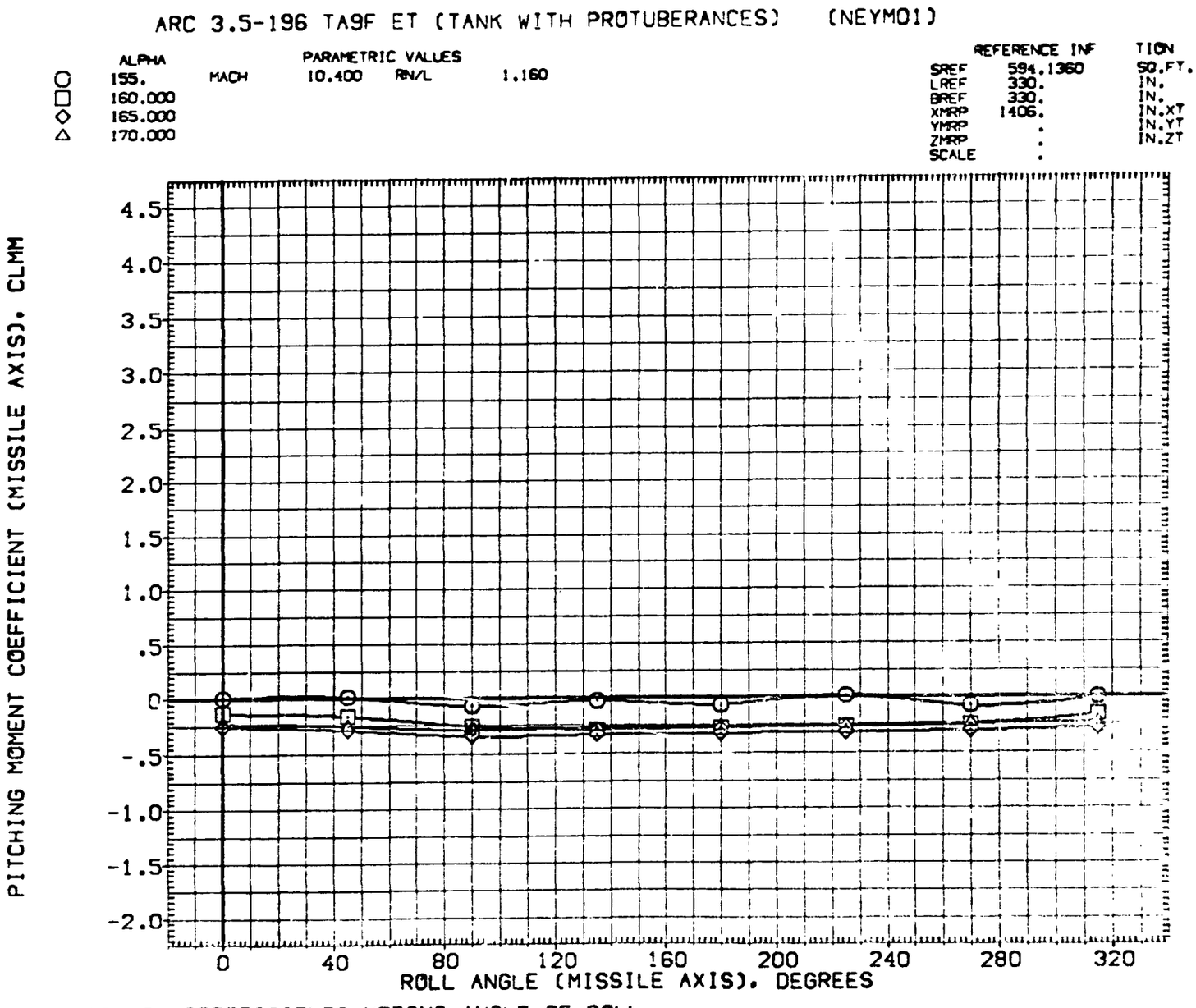


FIG. 9 COEFFICIENTS VERSUS ANGLE OF ROLL



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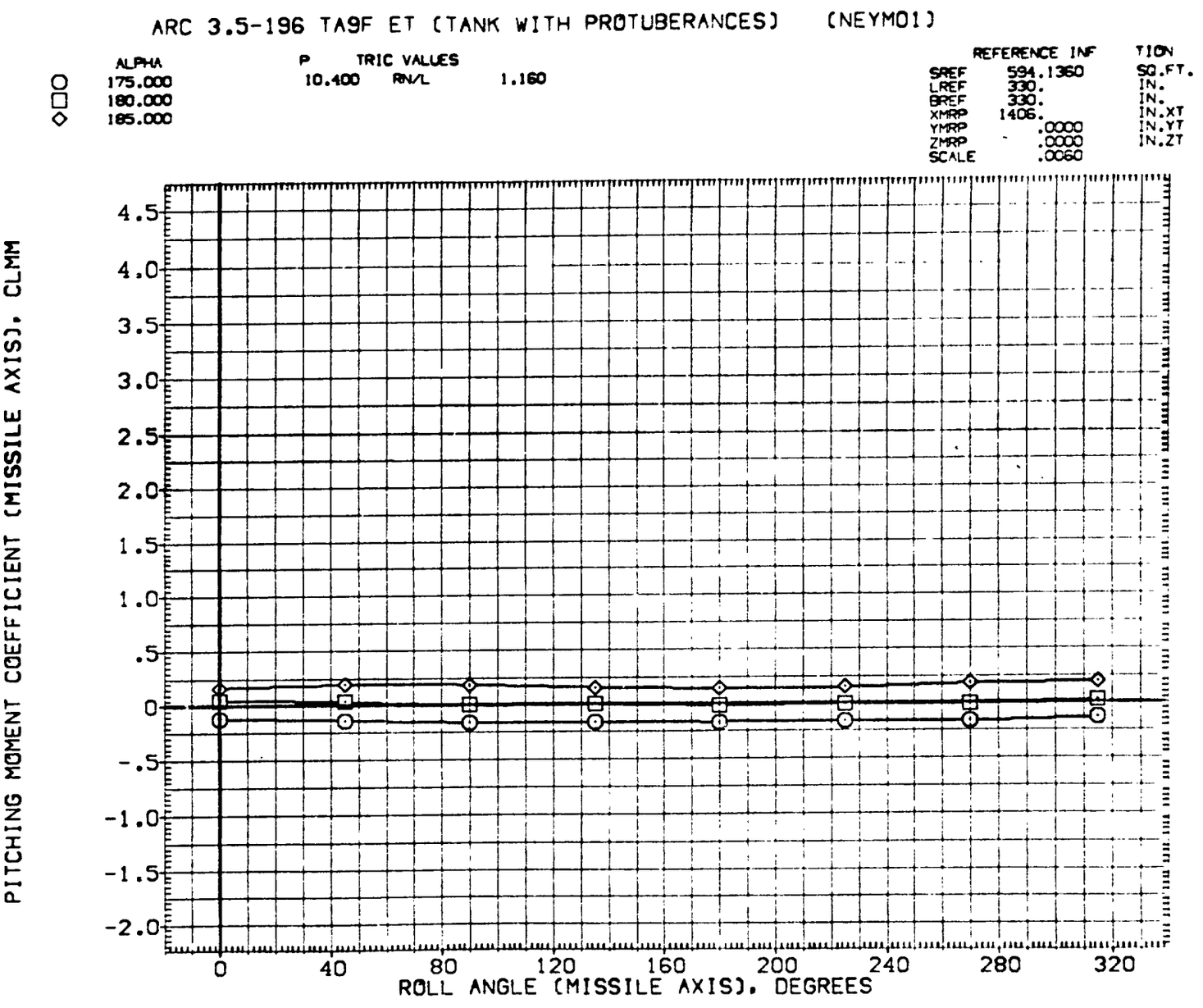
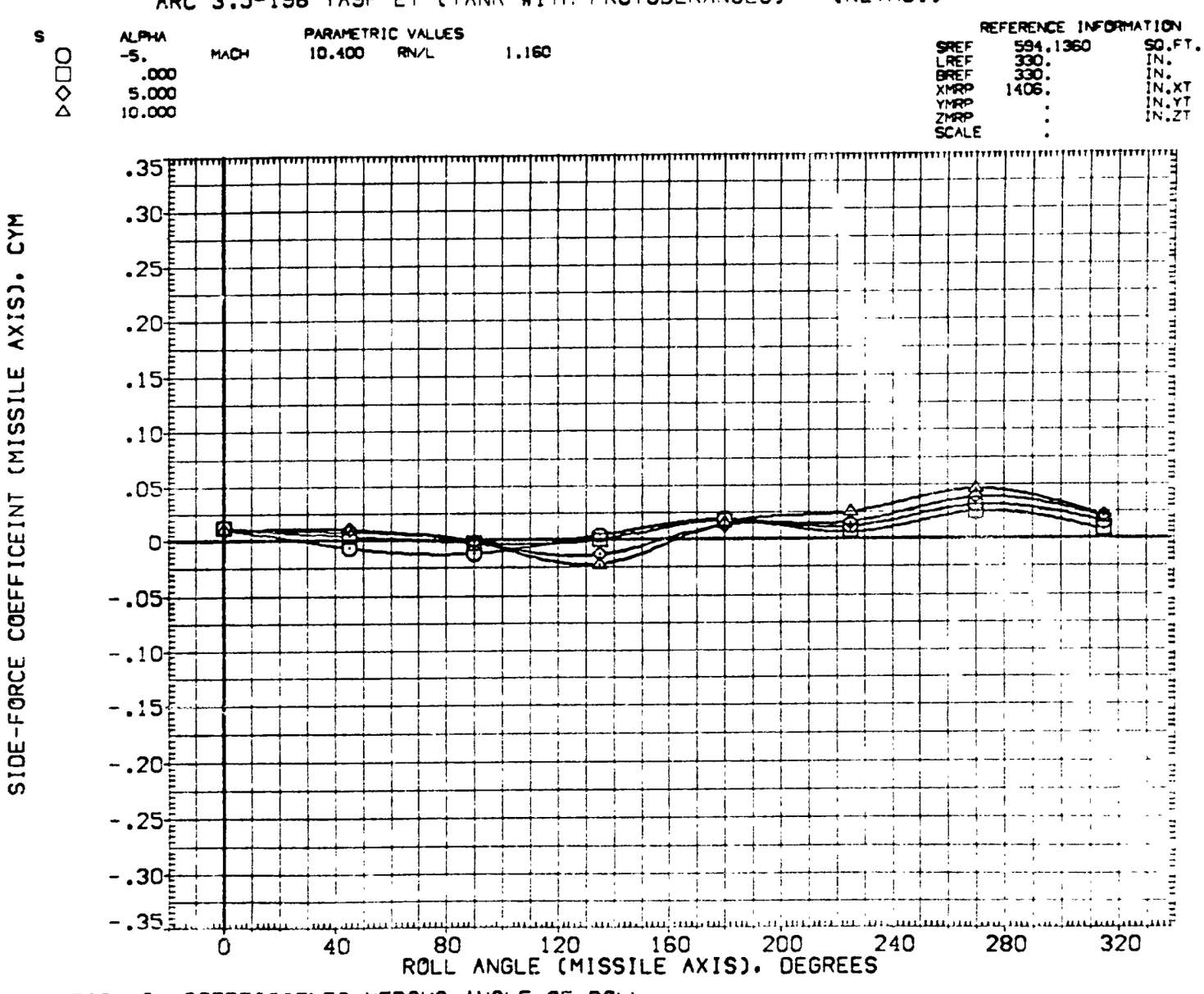


FIG. 9 COEFFICIENTS VERSUS ANGLE OF ROLL



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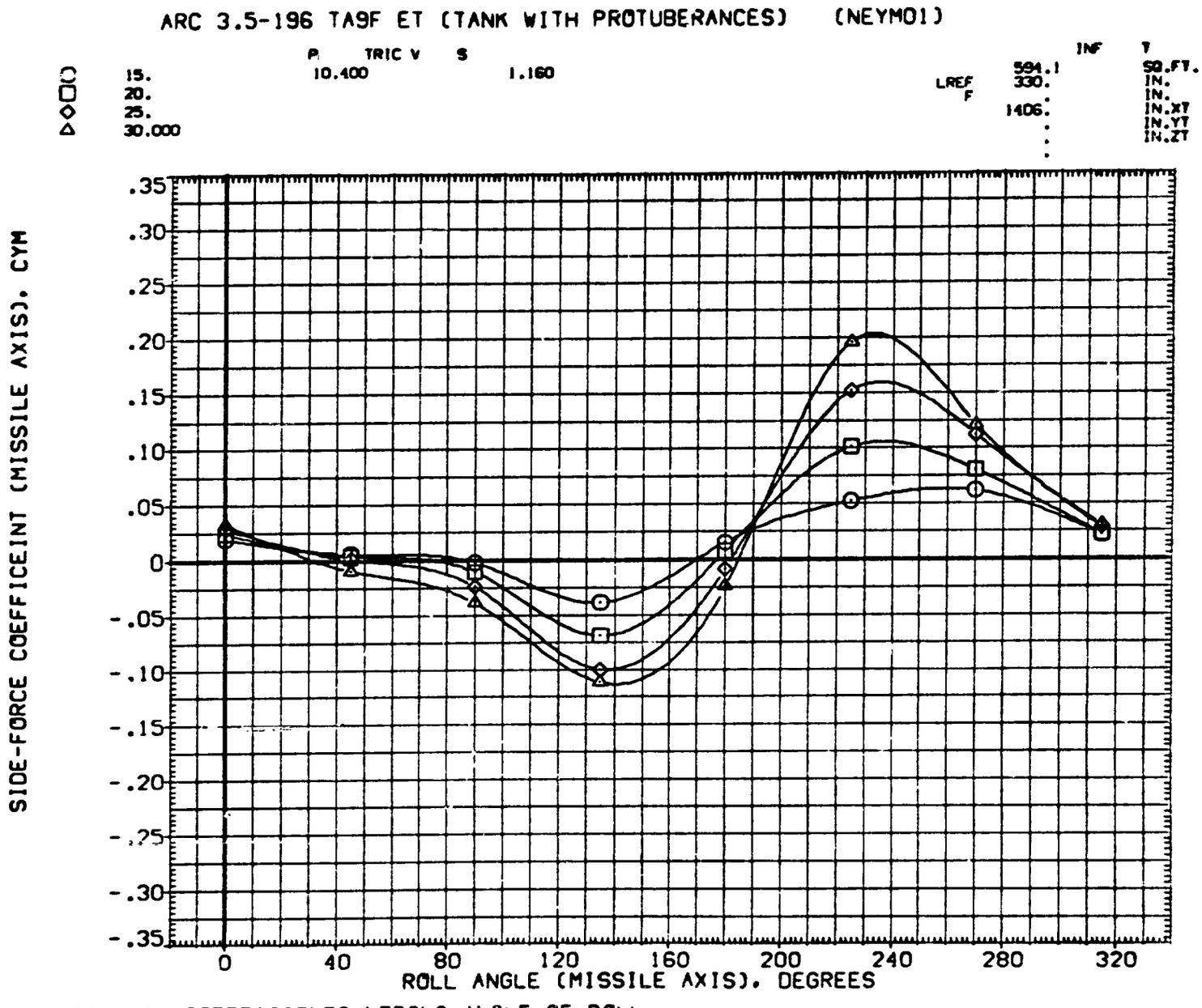

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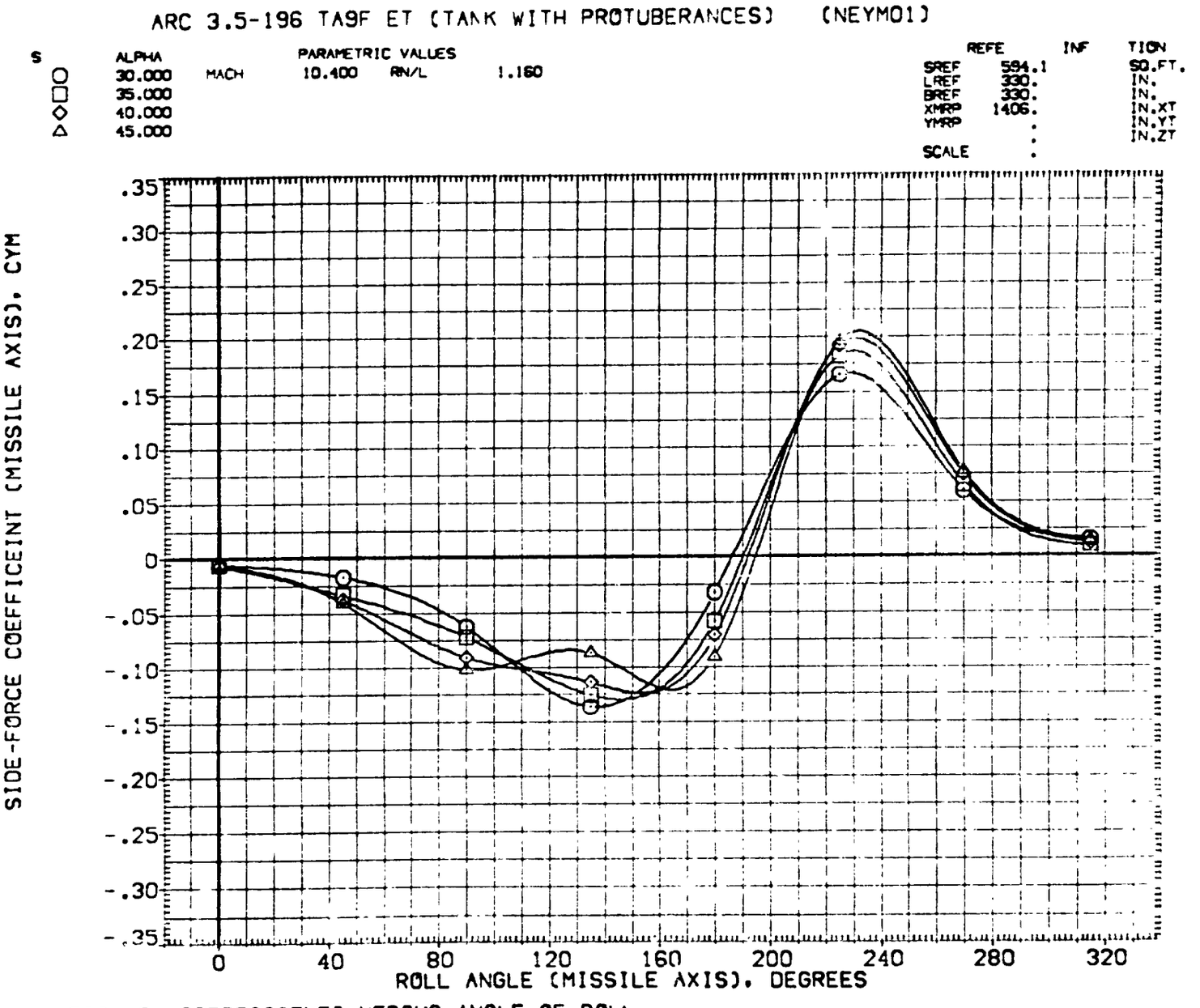

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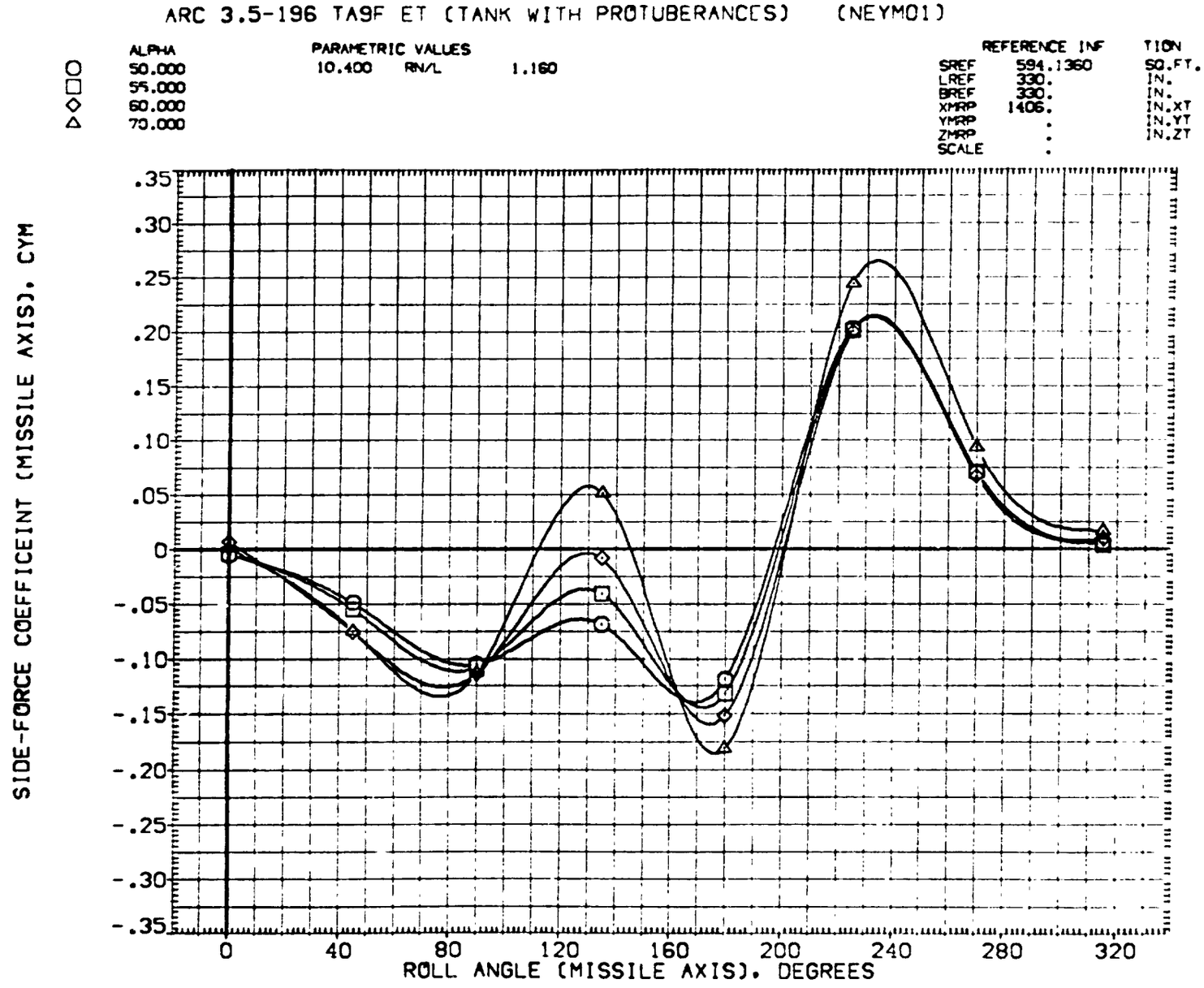
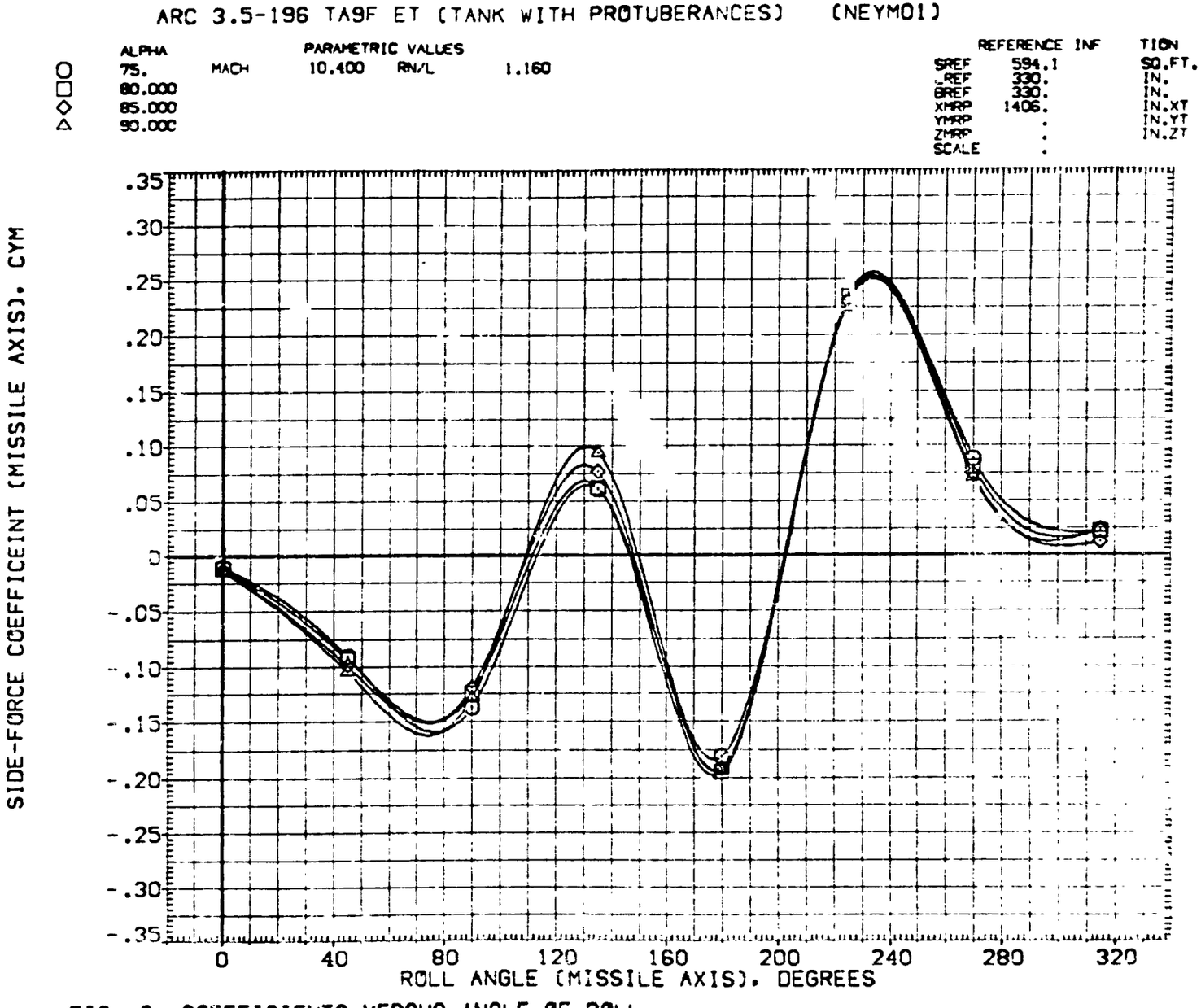


FIG. 9 COEFFICIENTS VERSUS ANGLE OF ROLL



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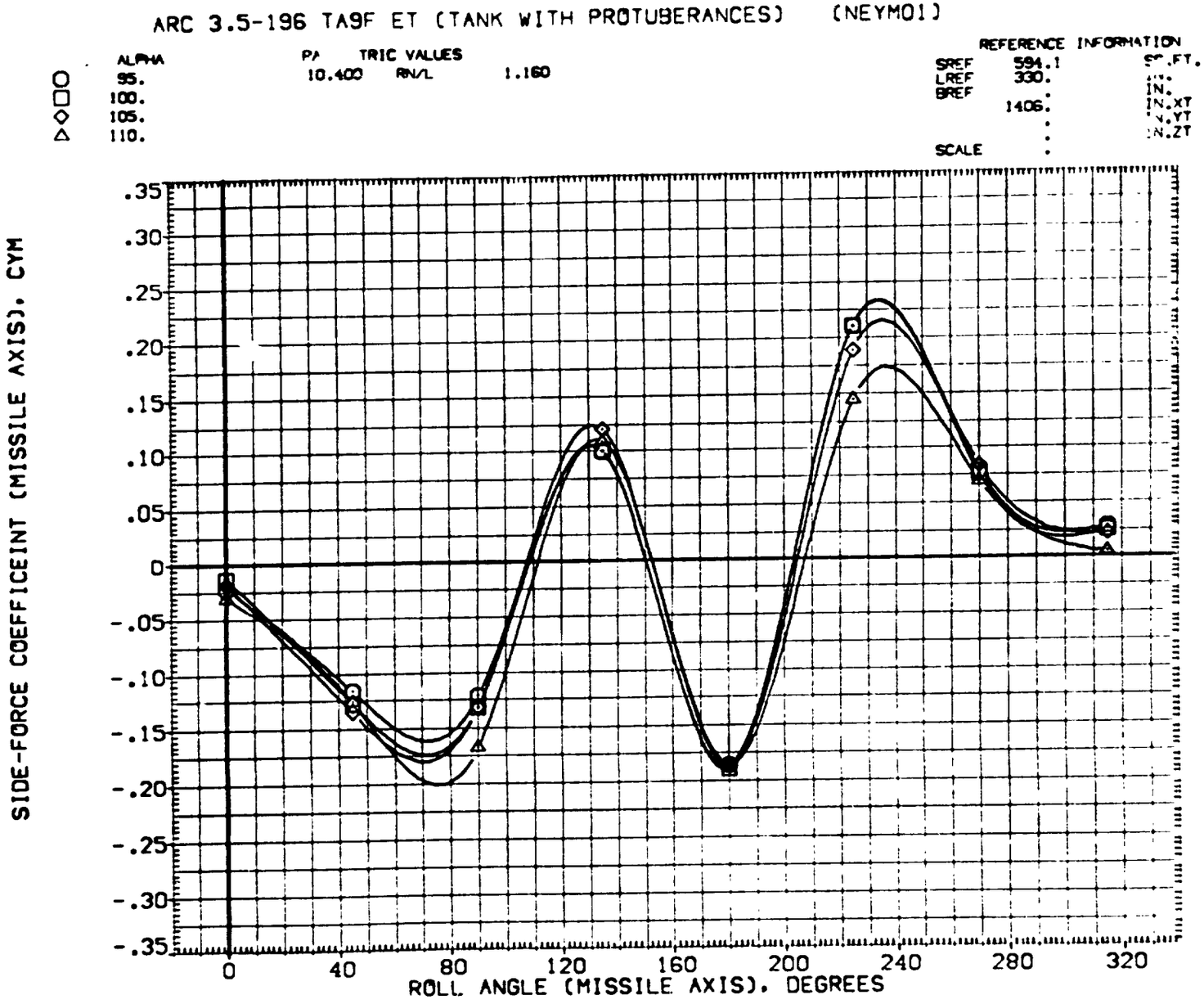

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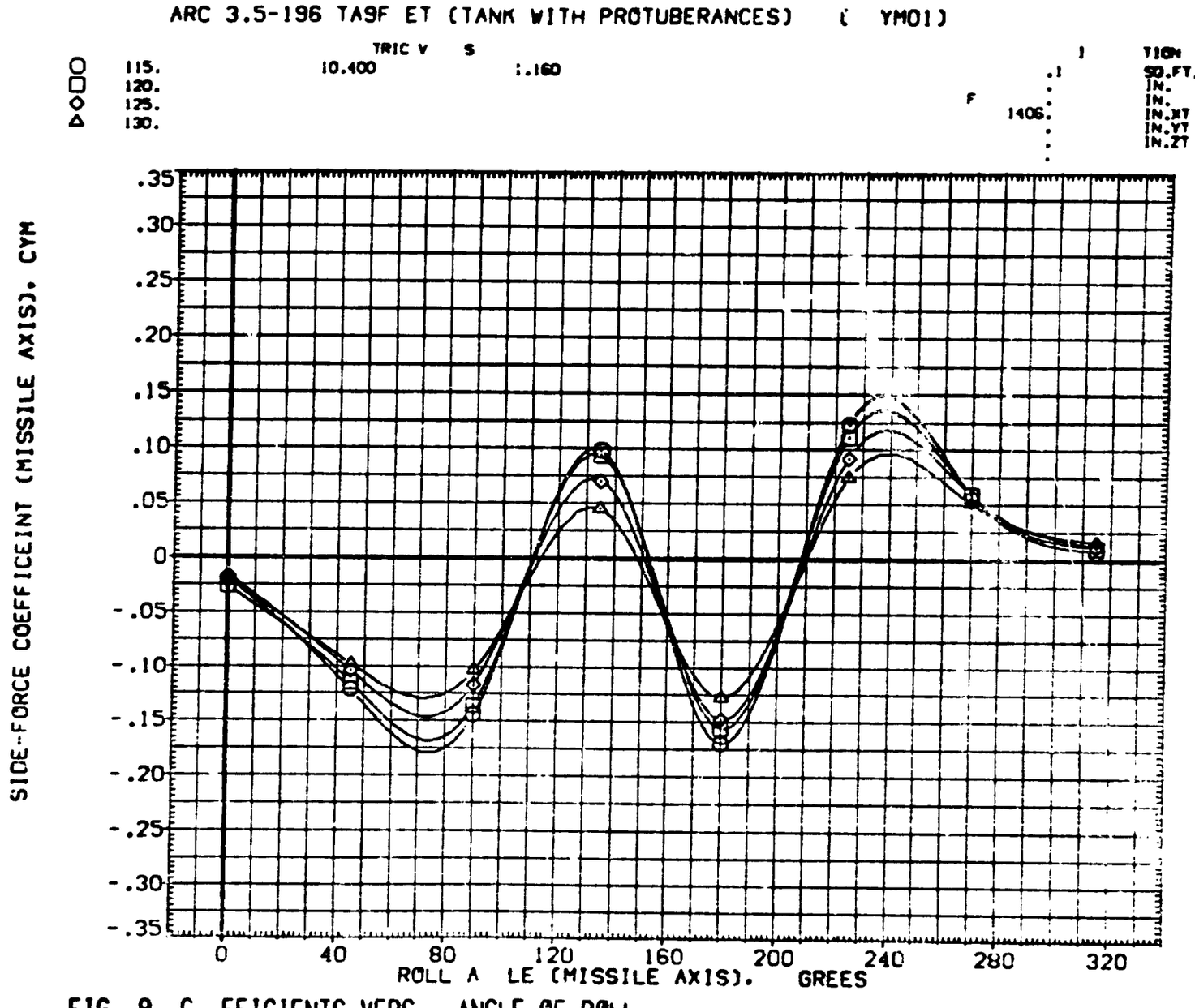
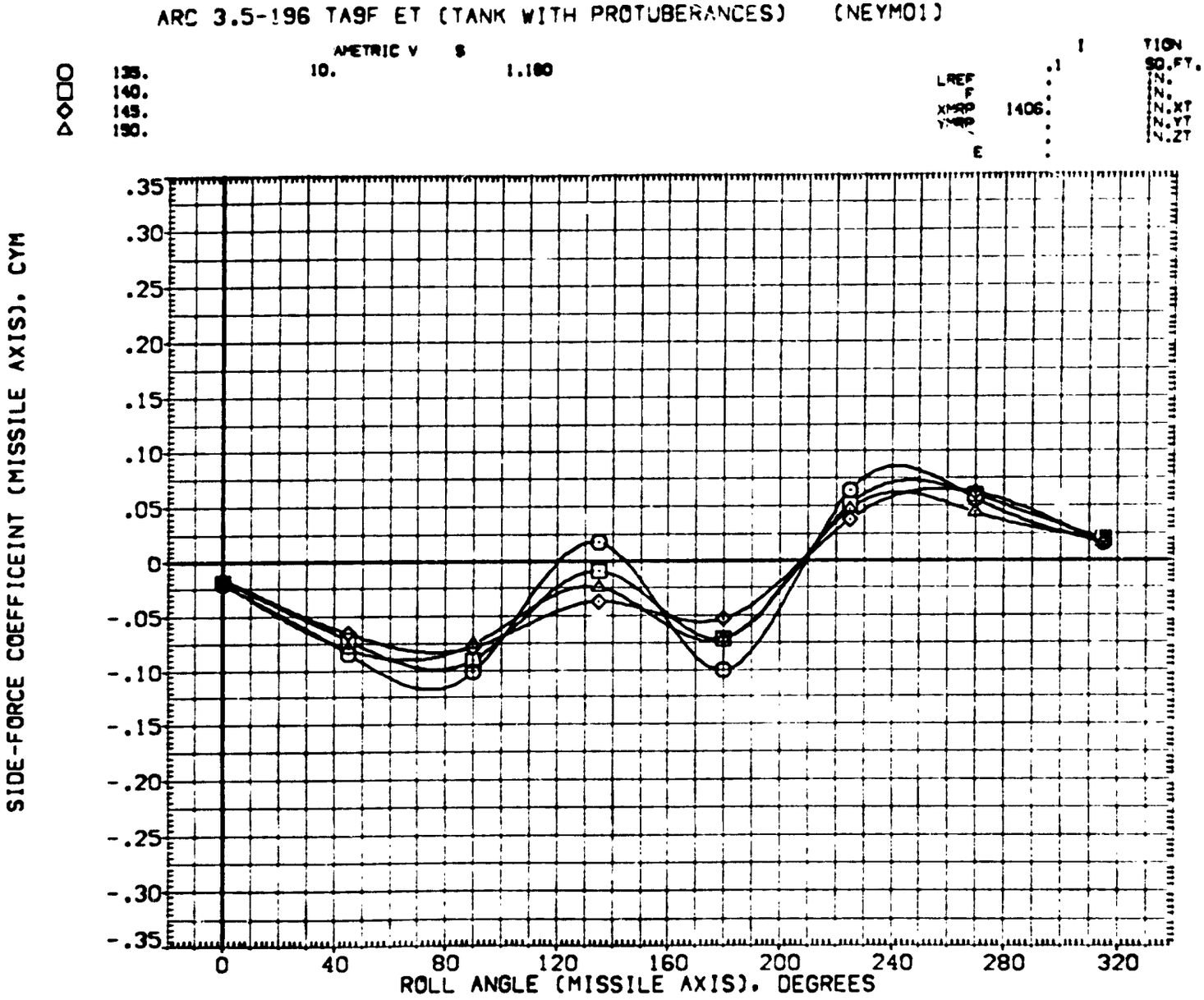


FIG. 9 C FFICIENTS VERS ANGLE OF ROLL



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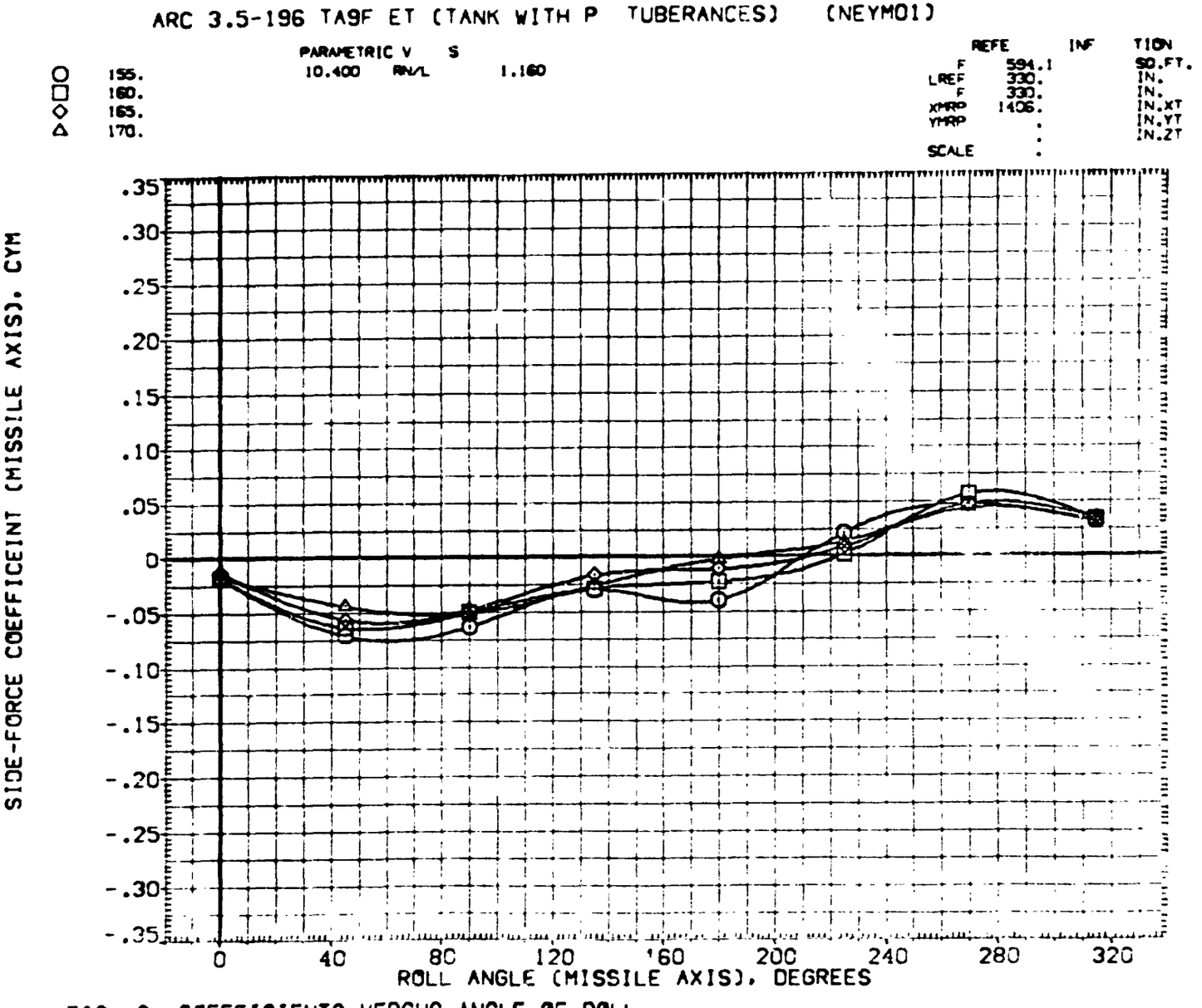

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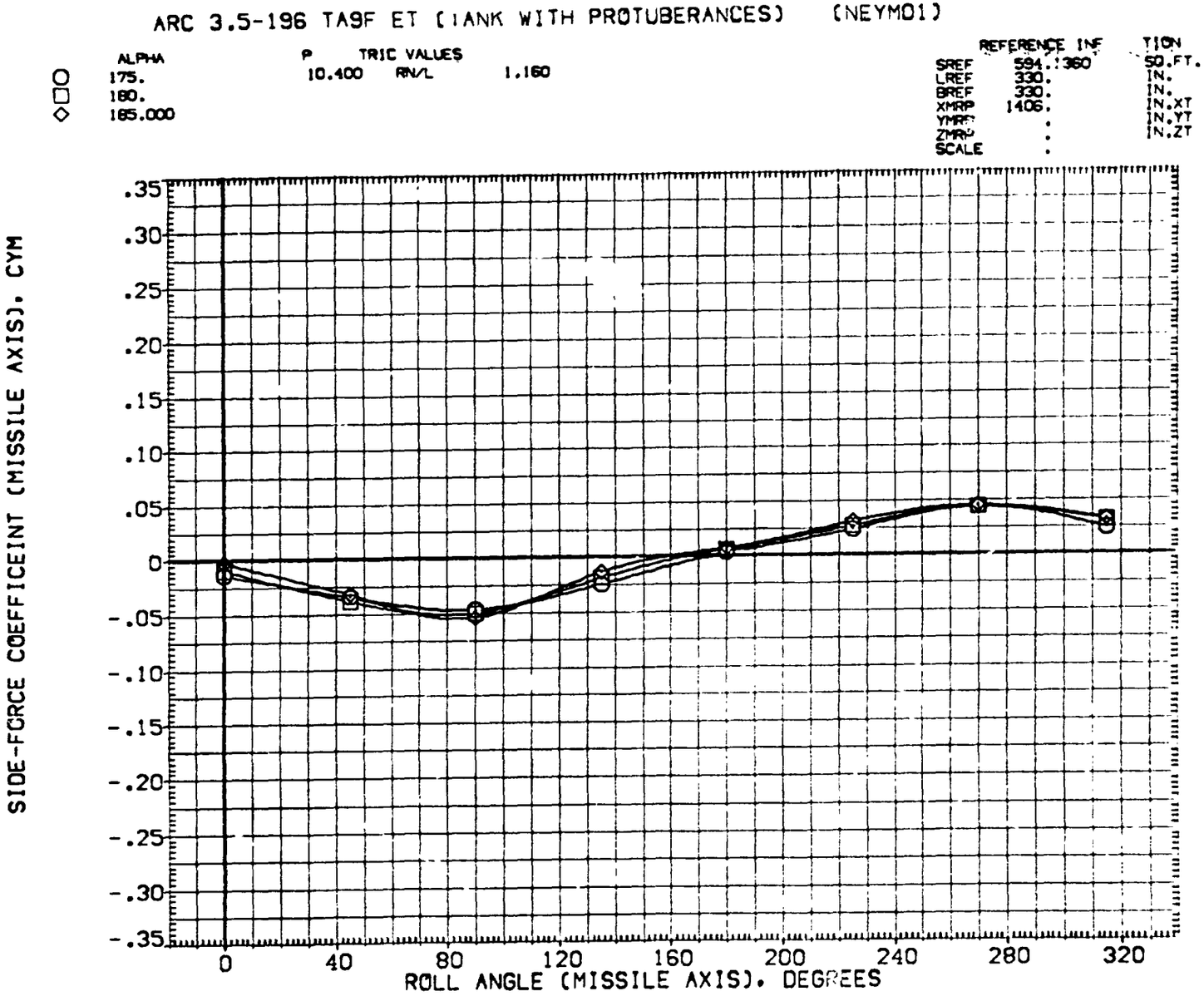

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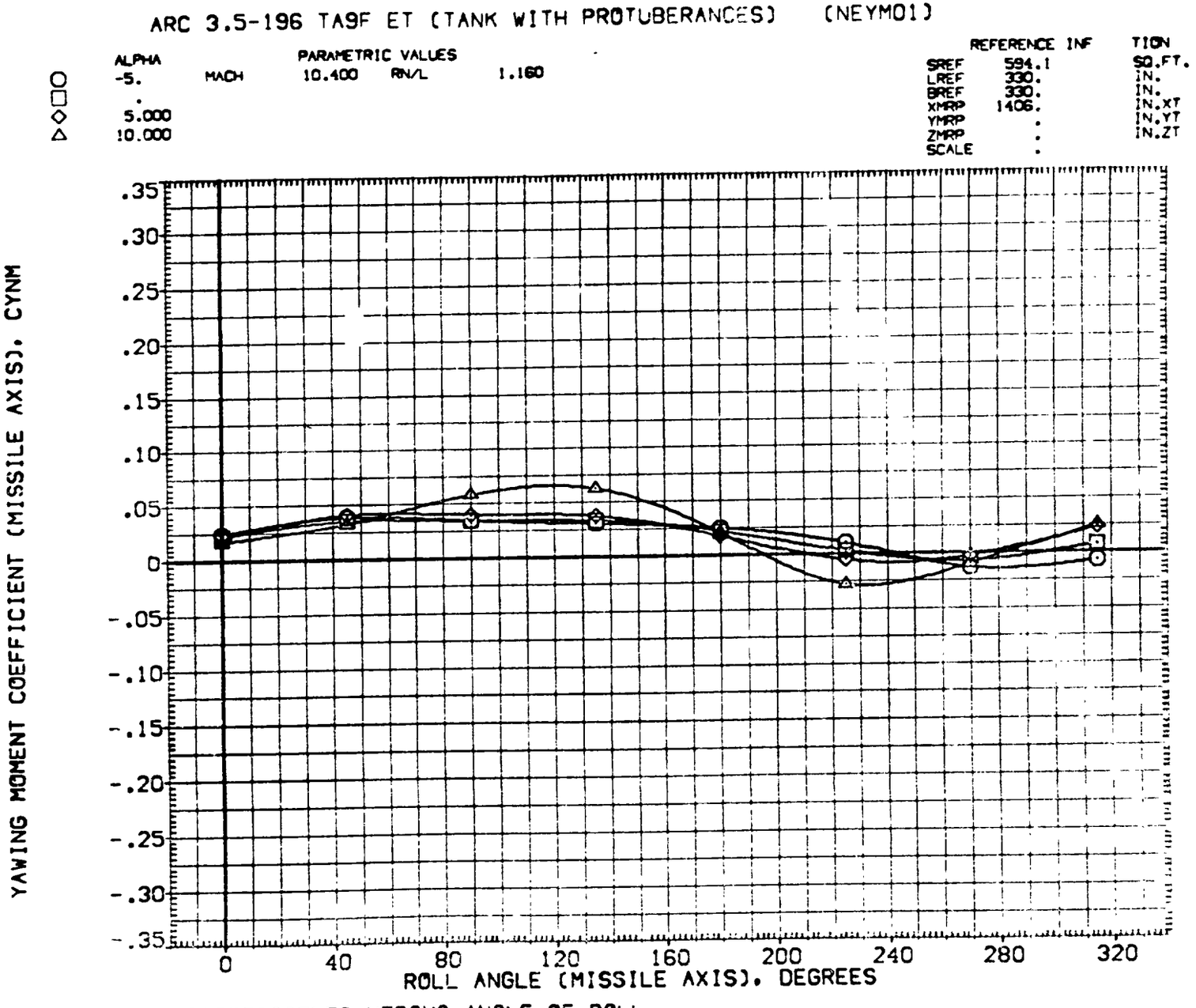

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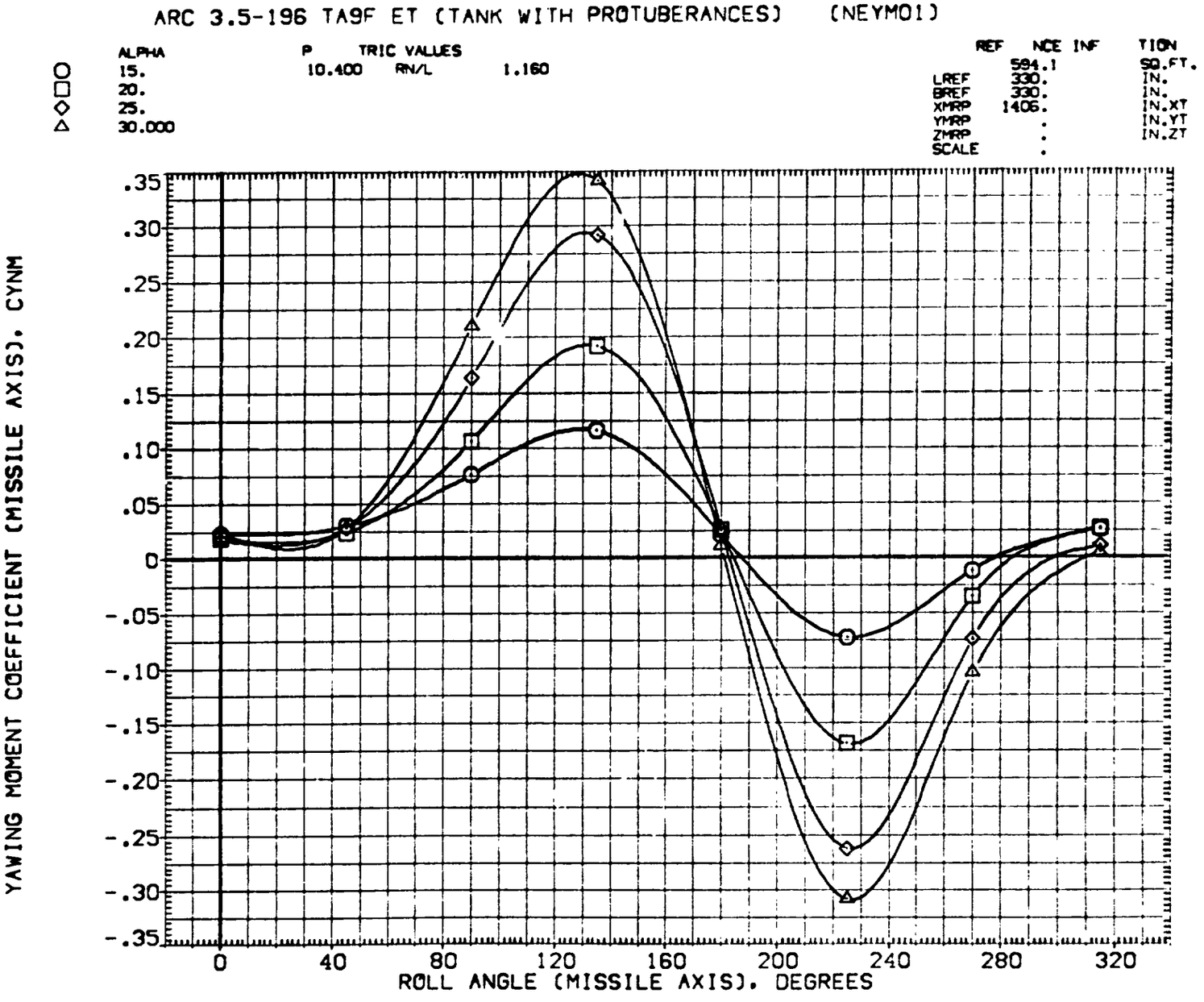

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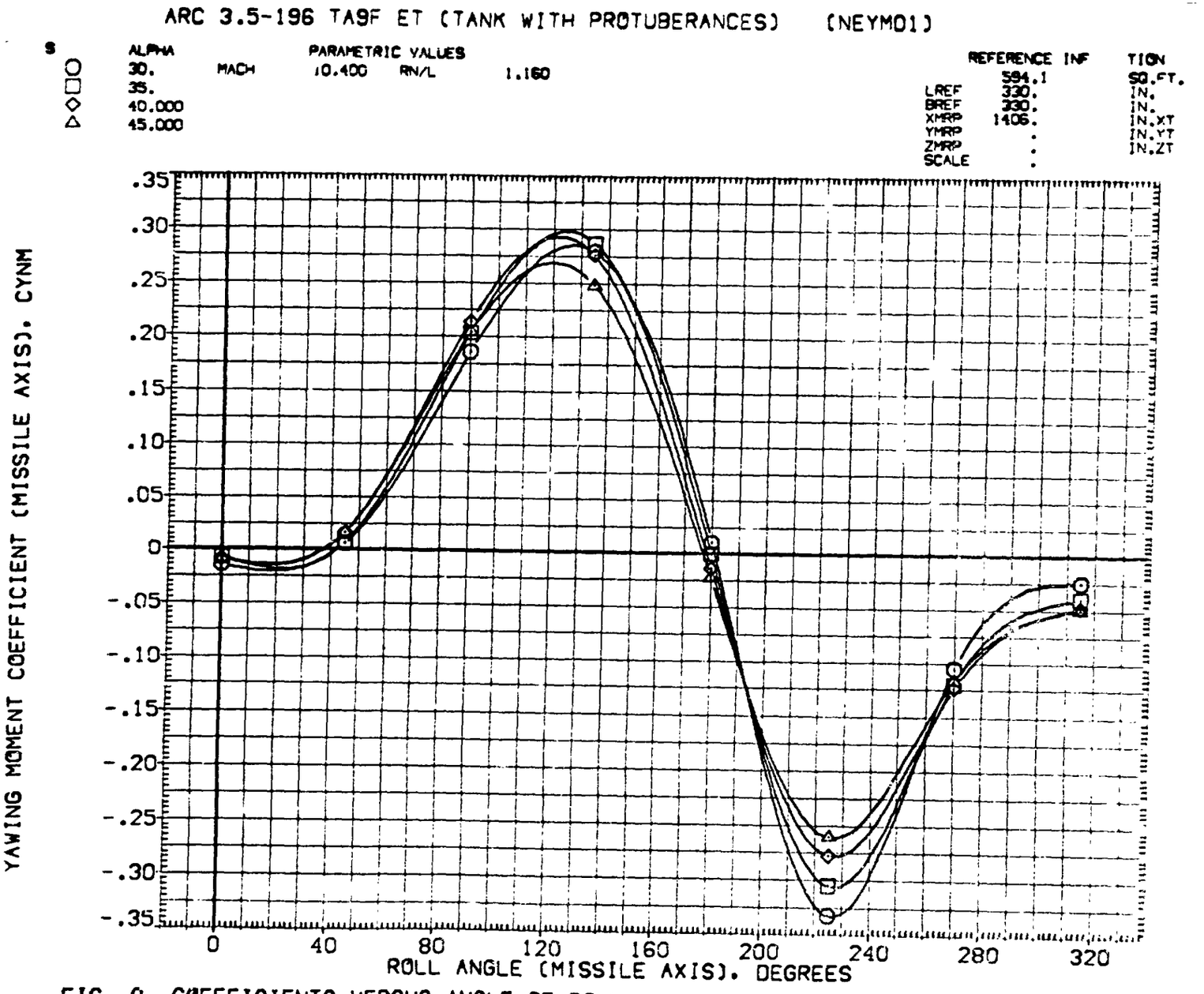

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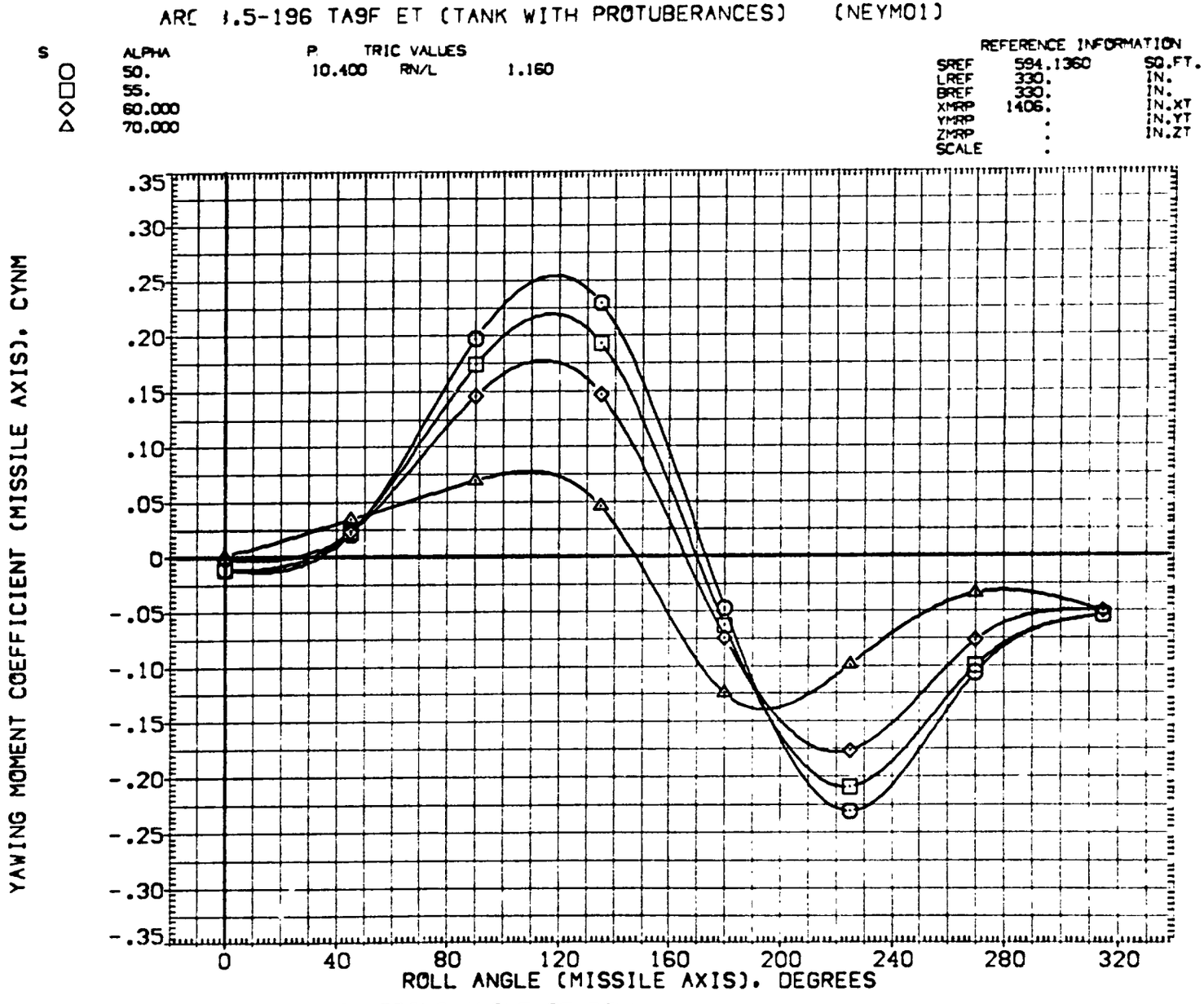

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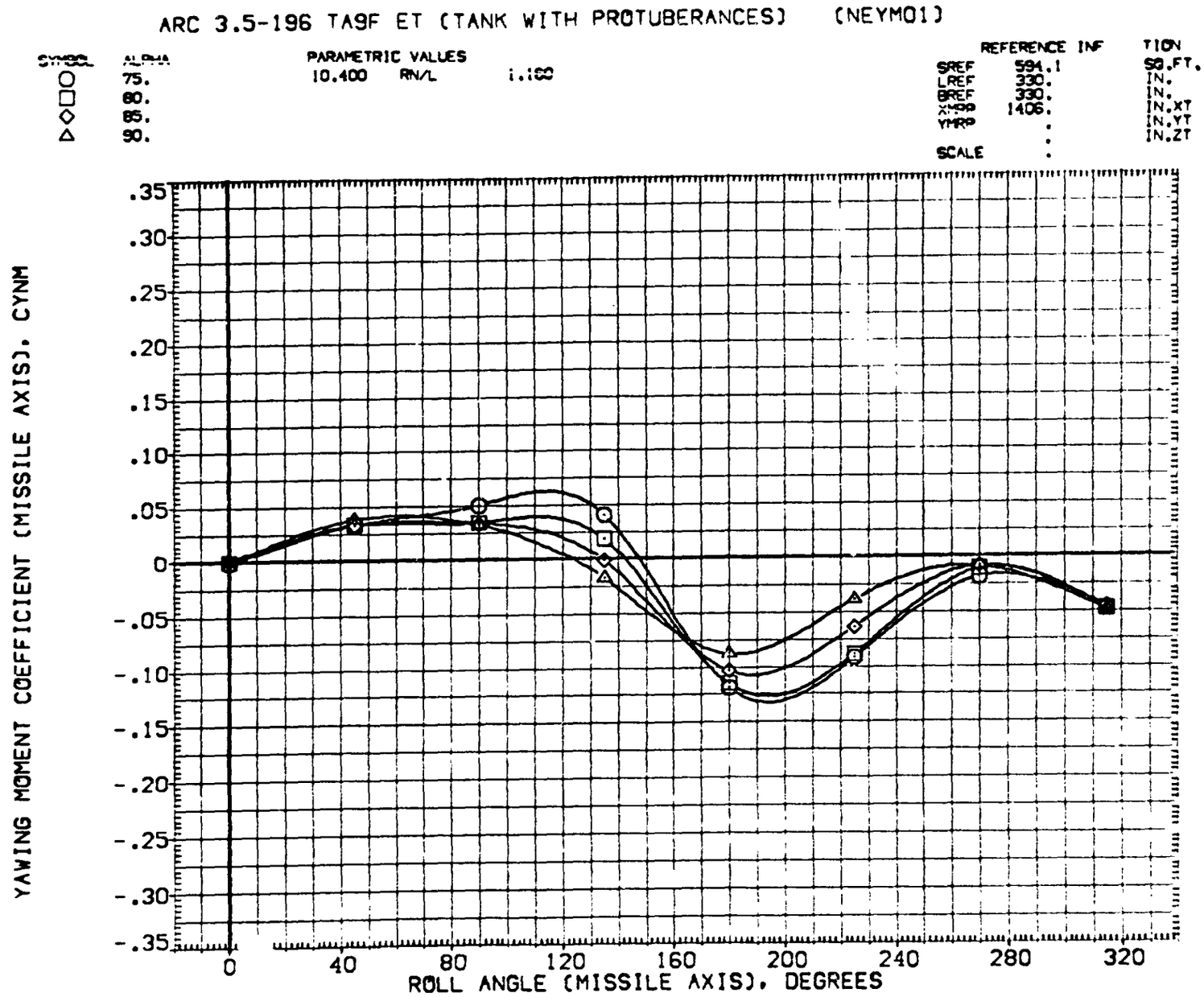

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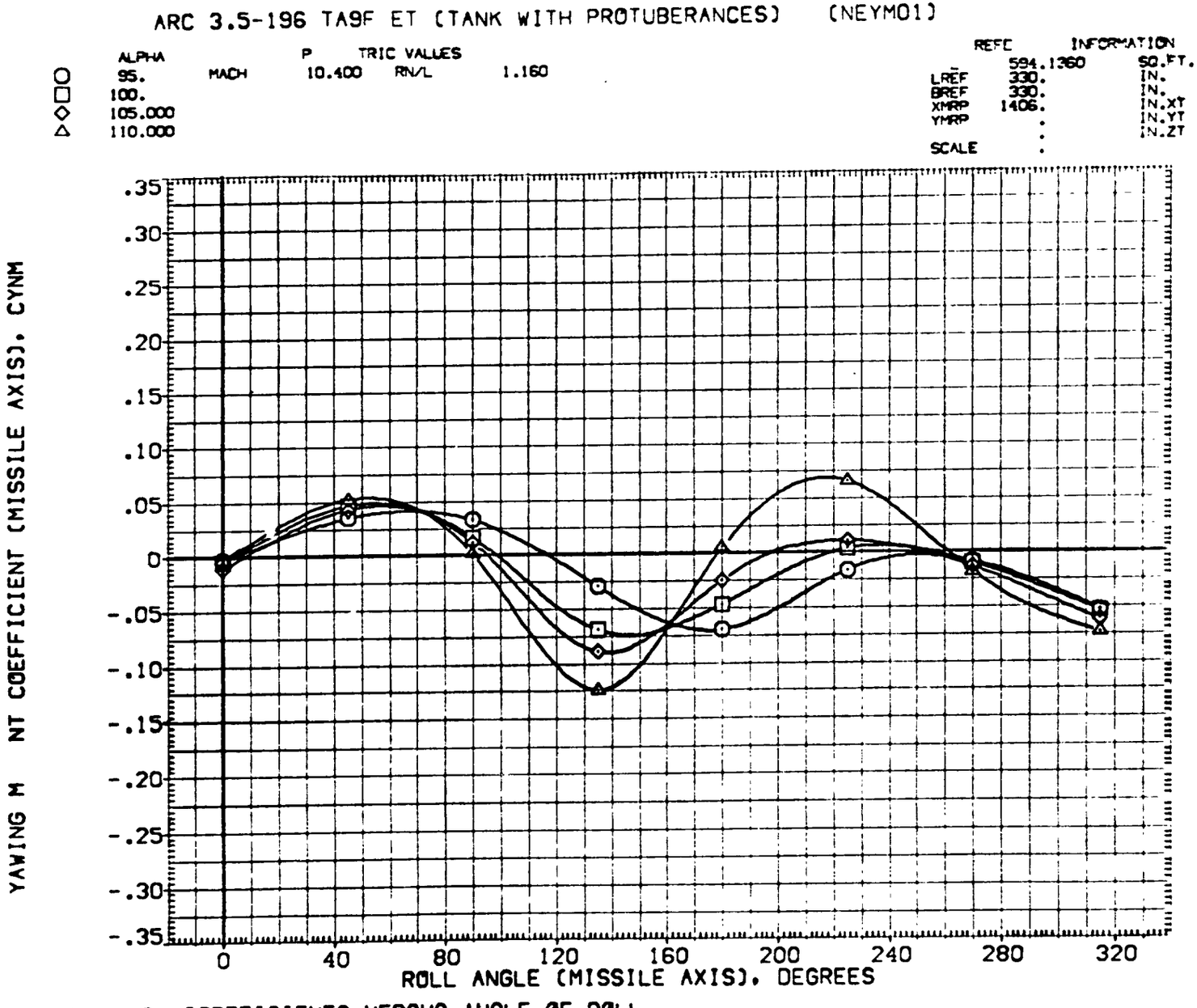

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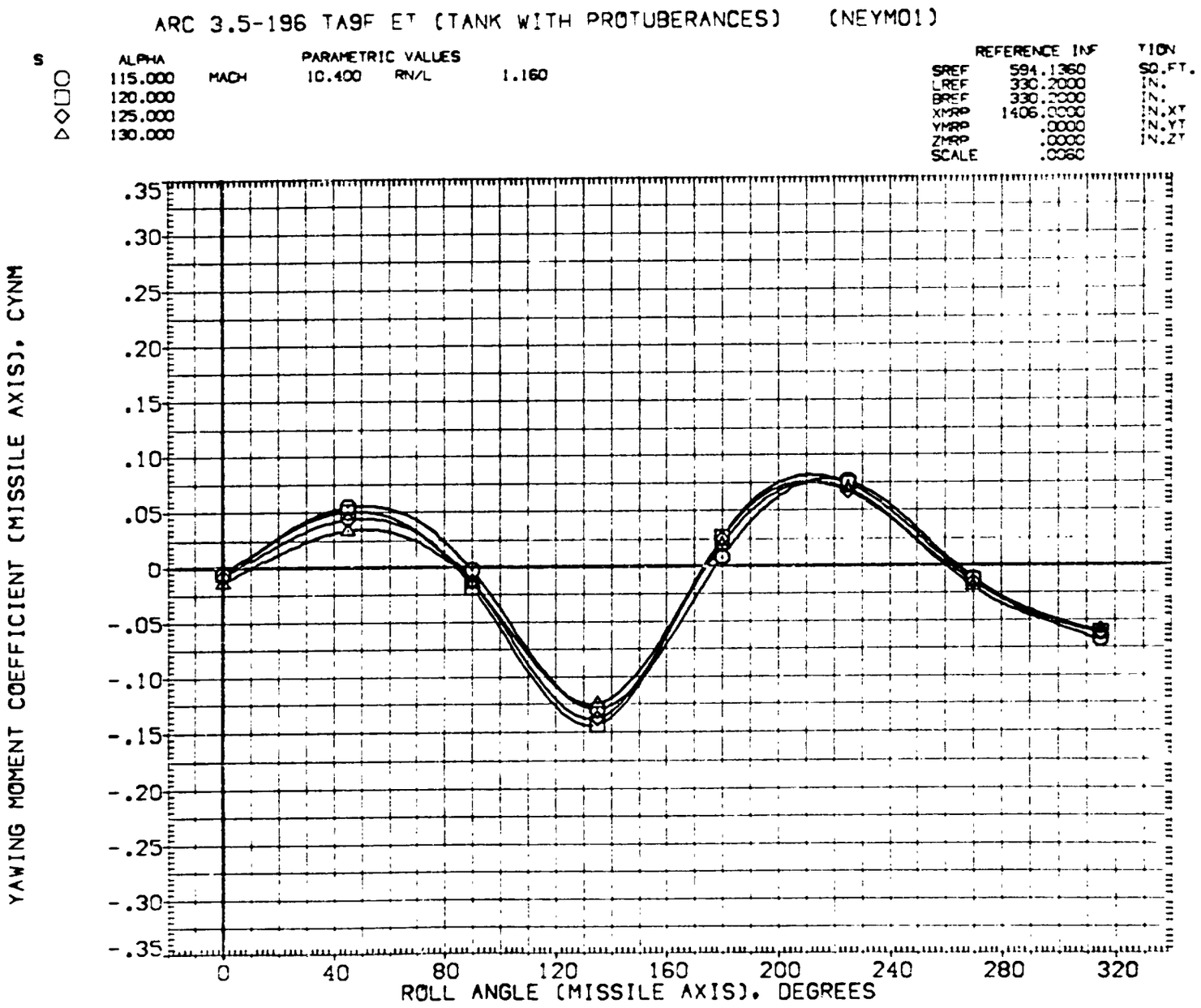

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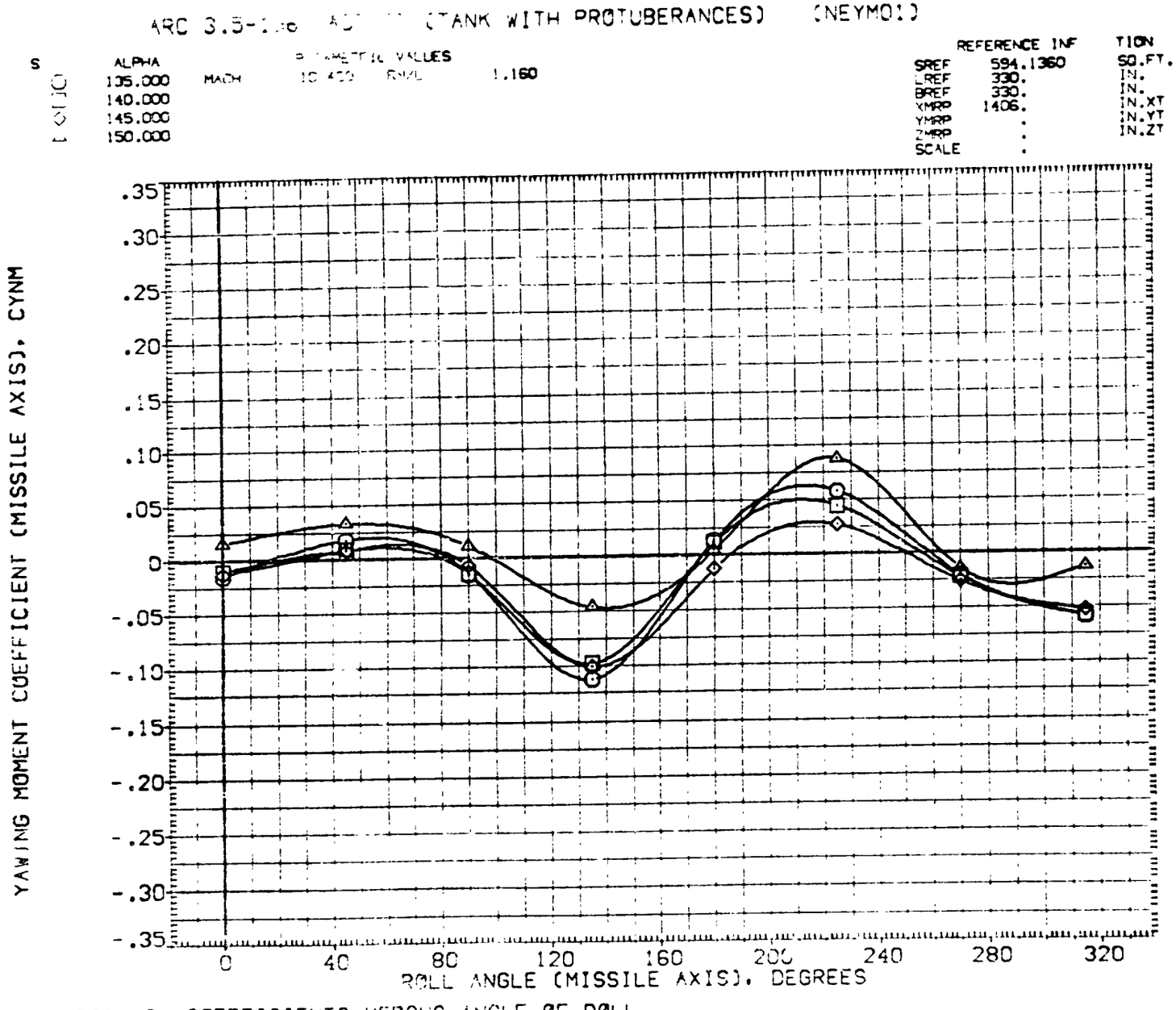

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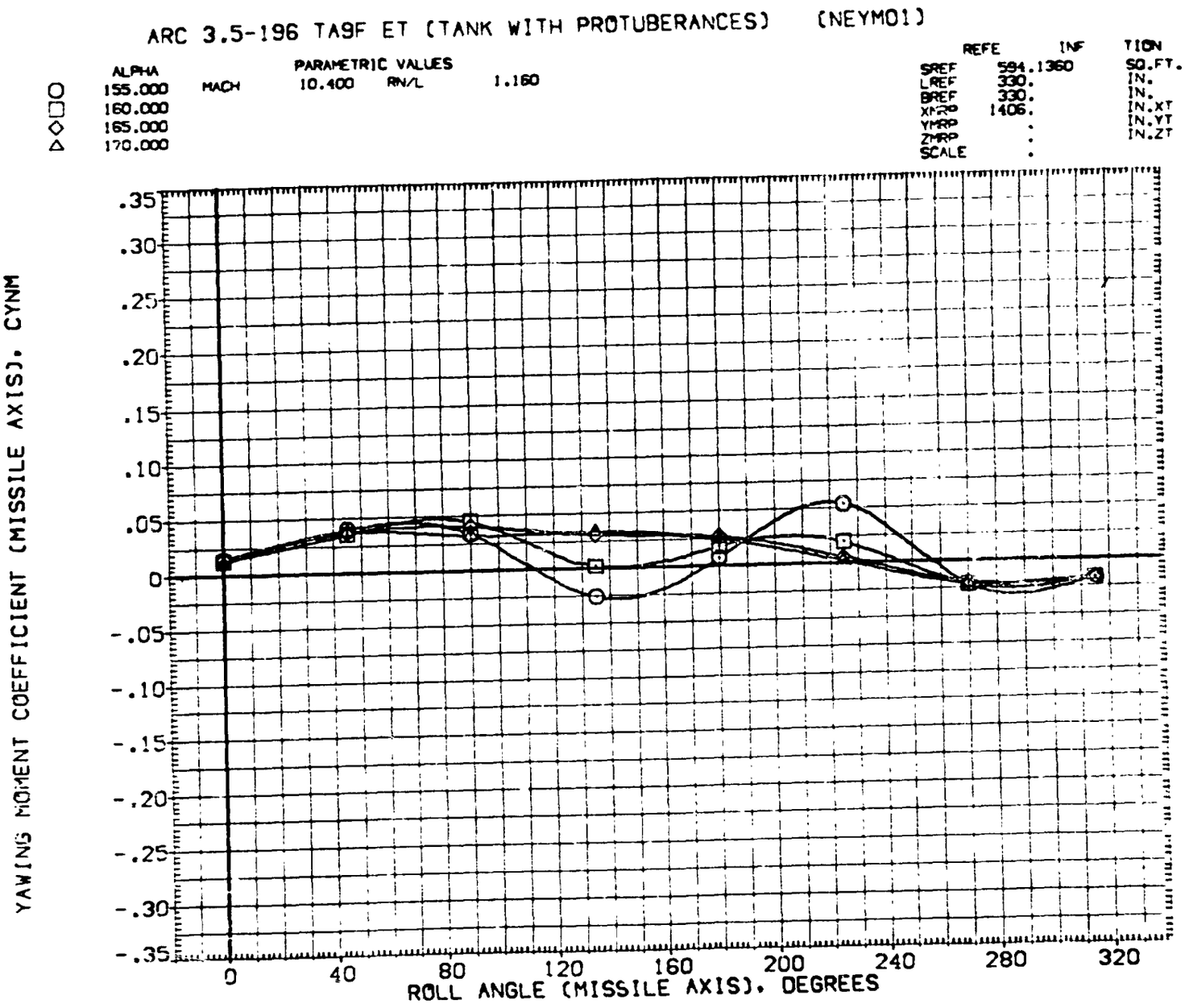

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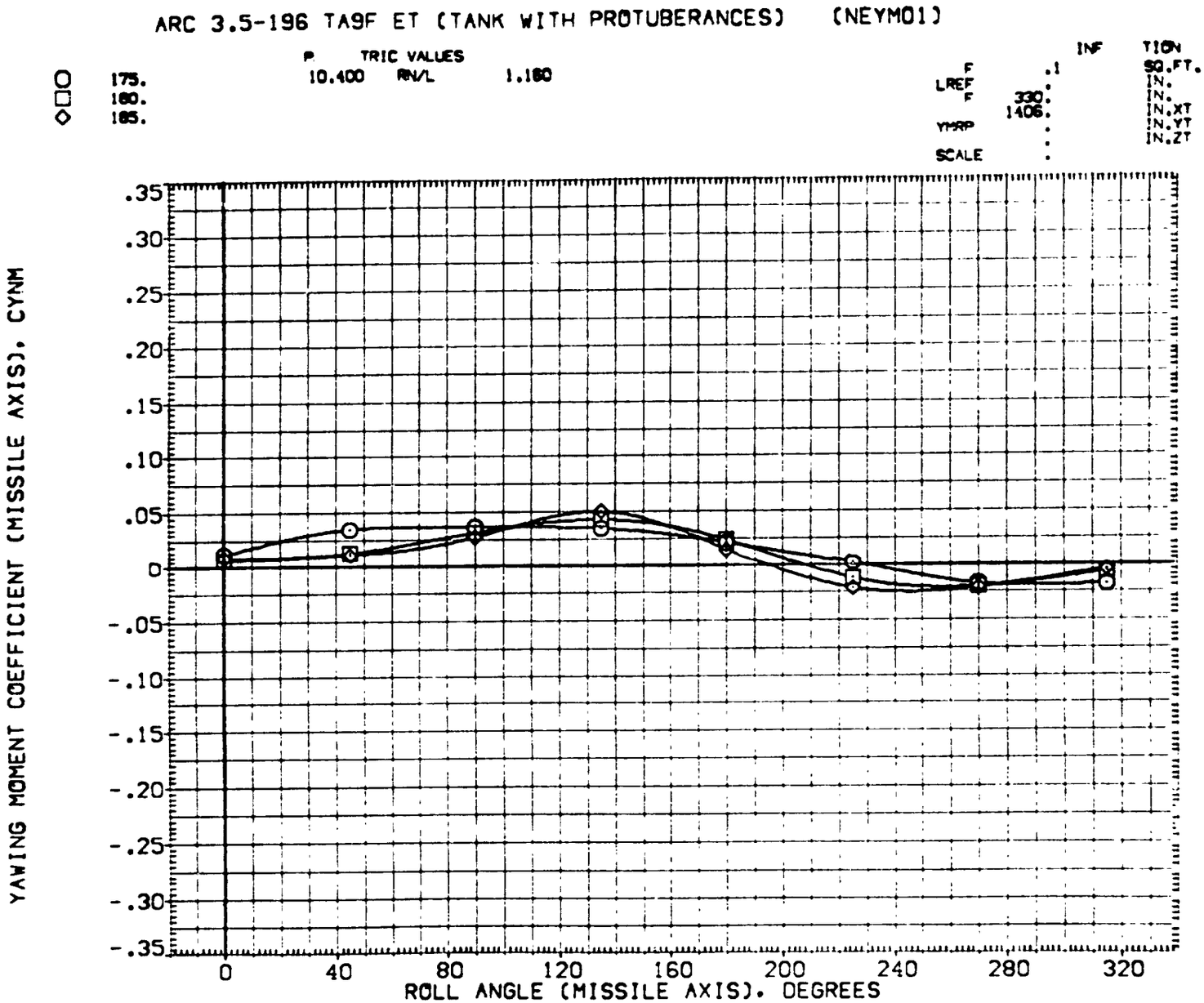

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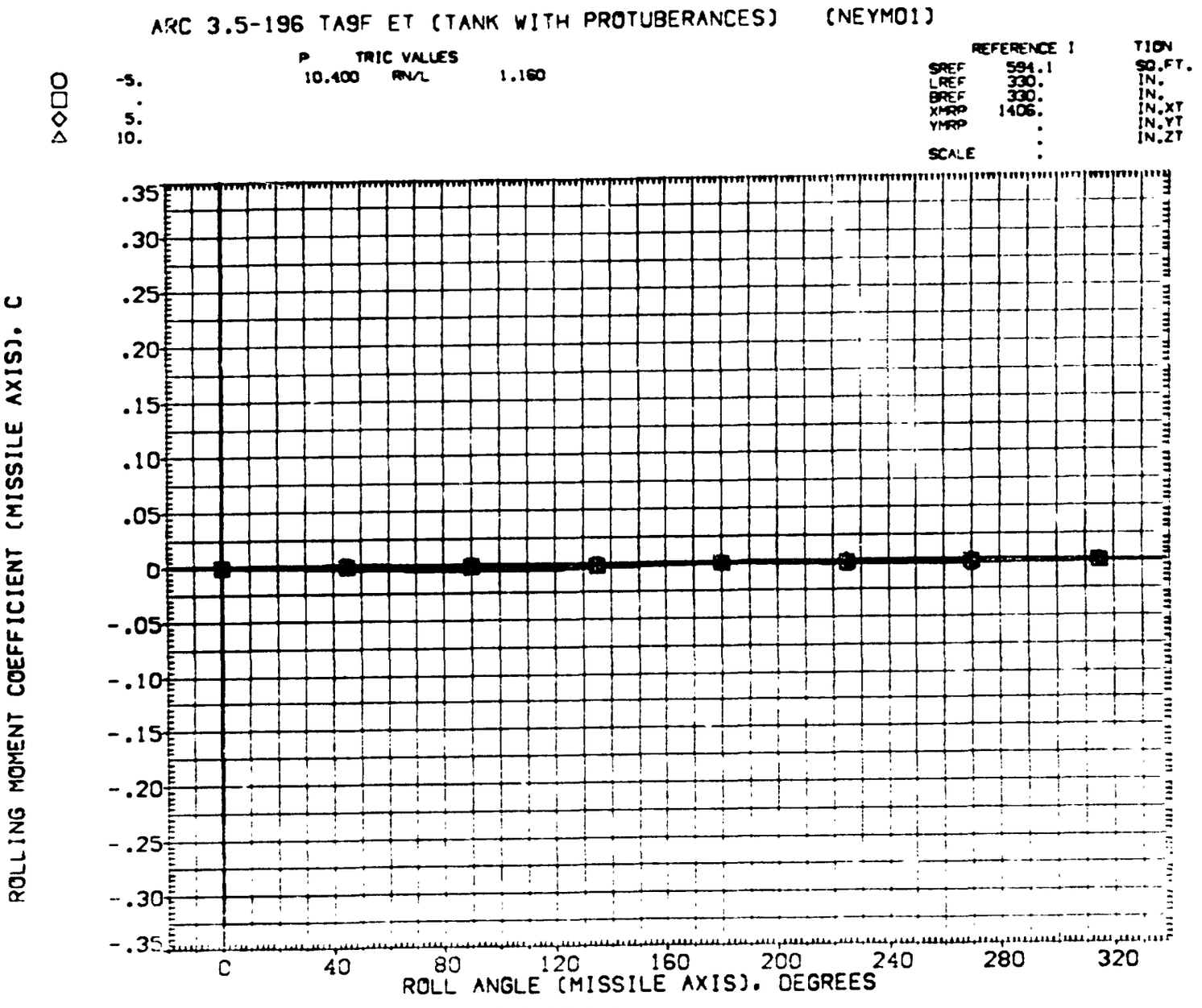

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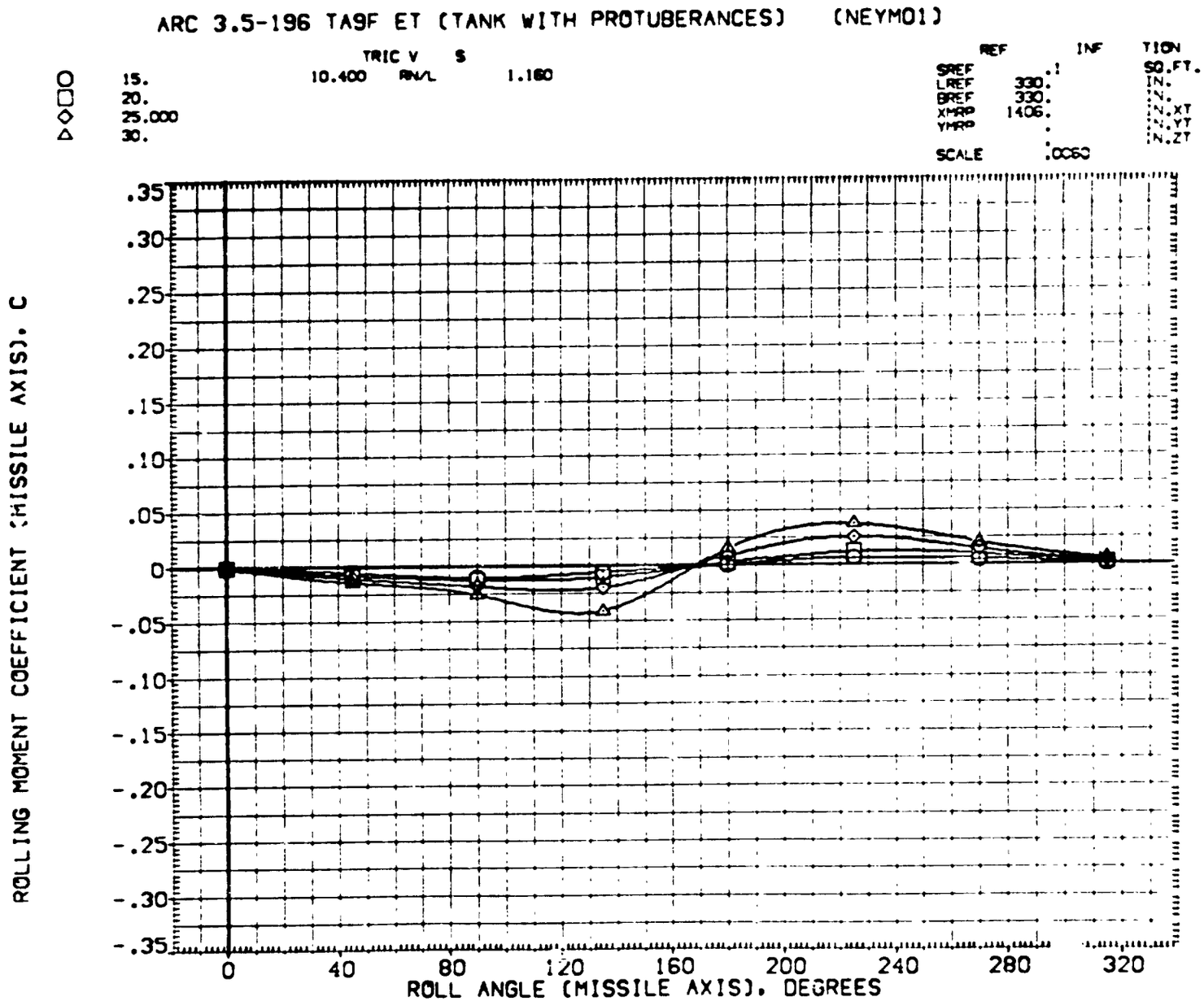

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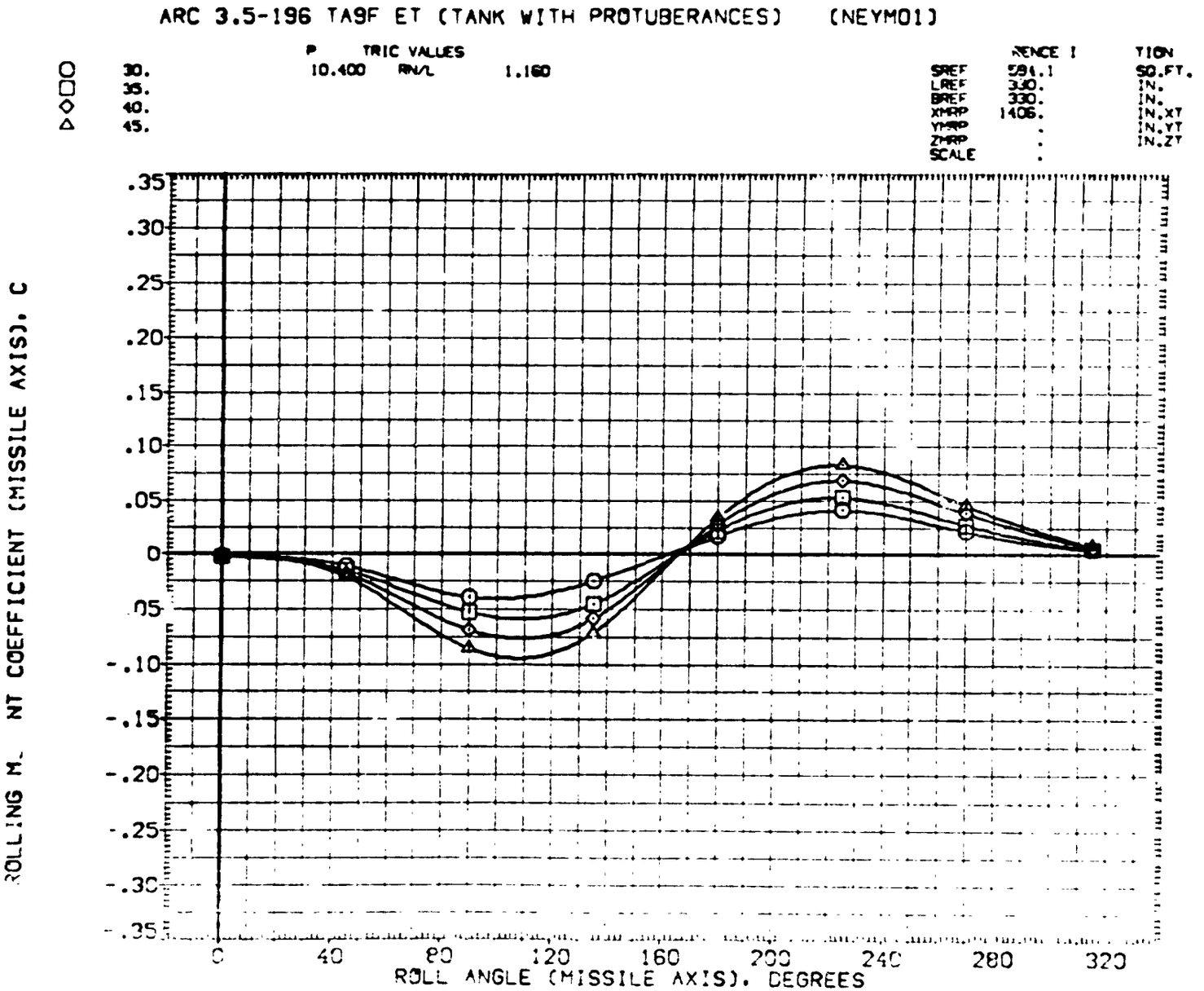

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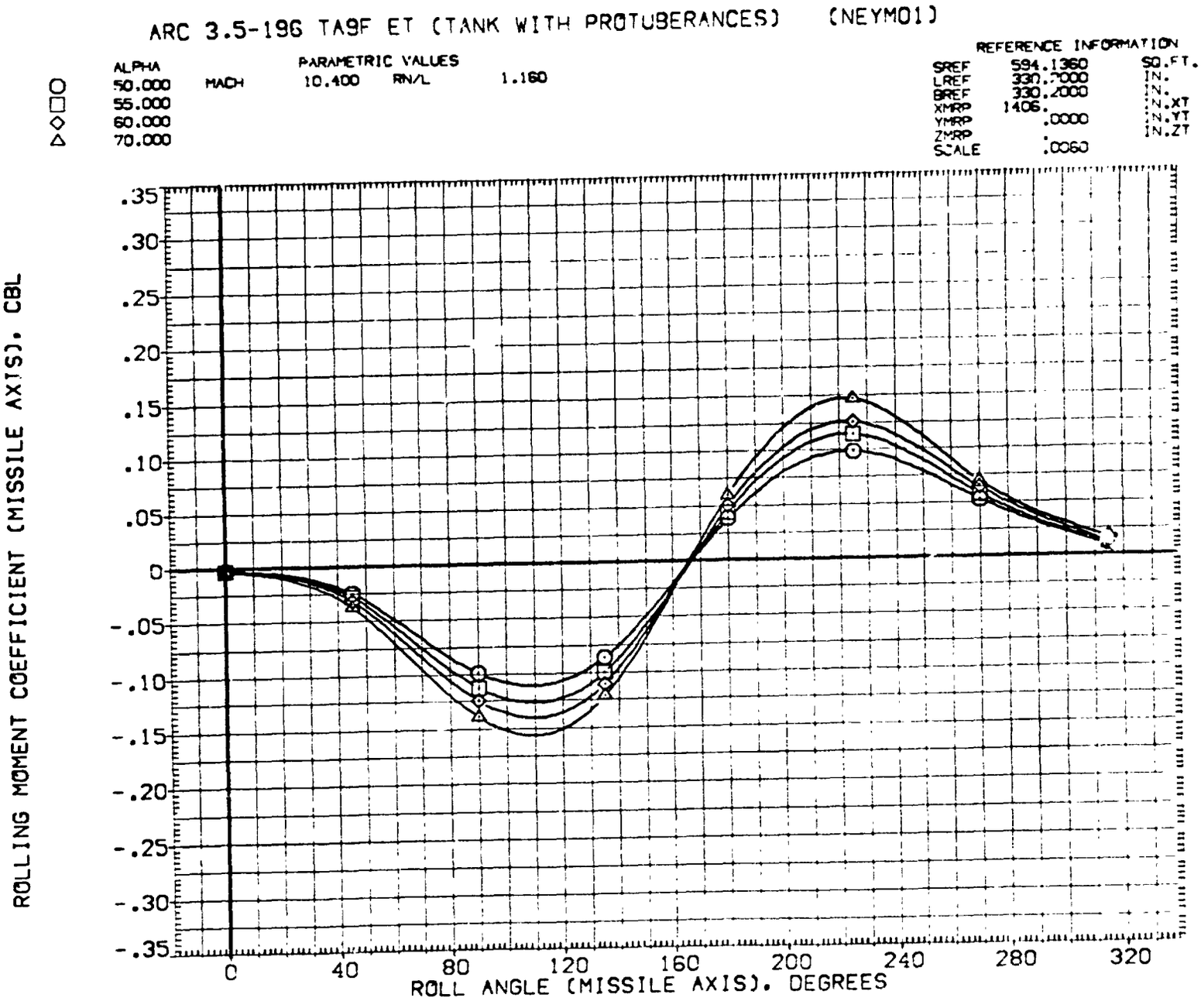

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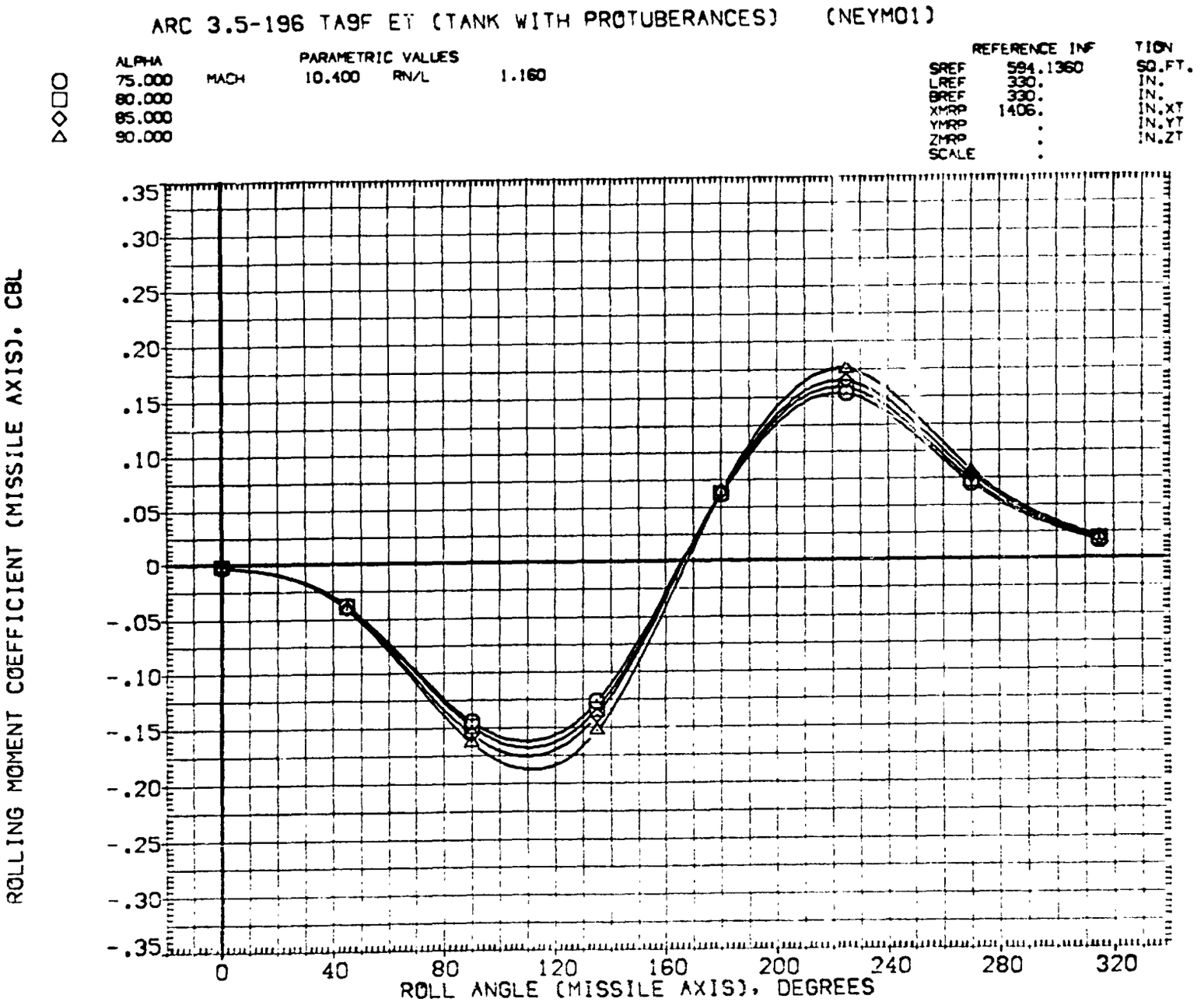

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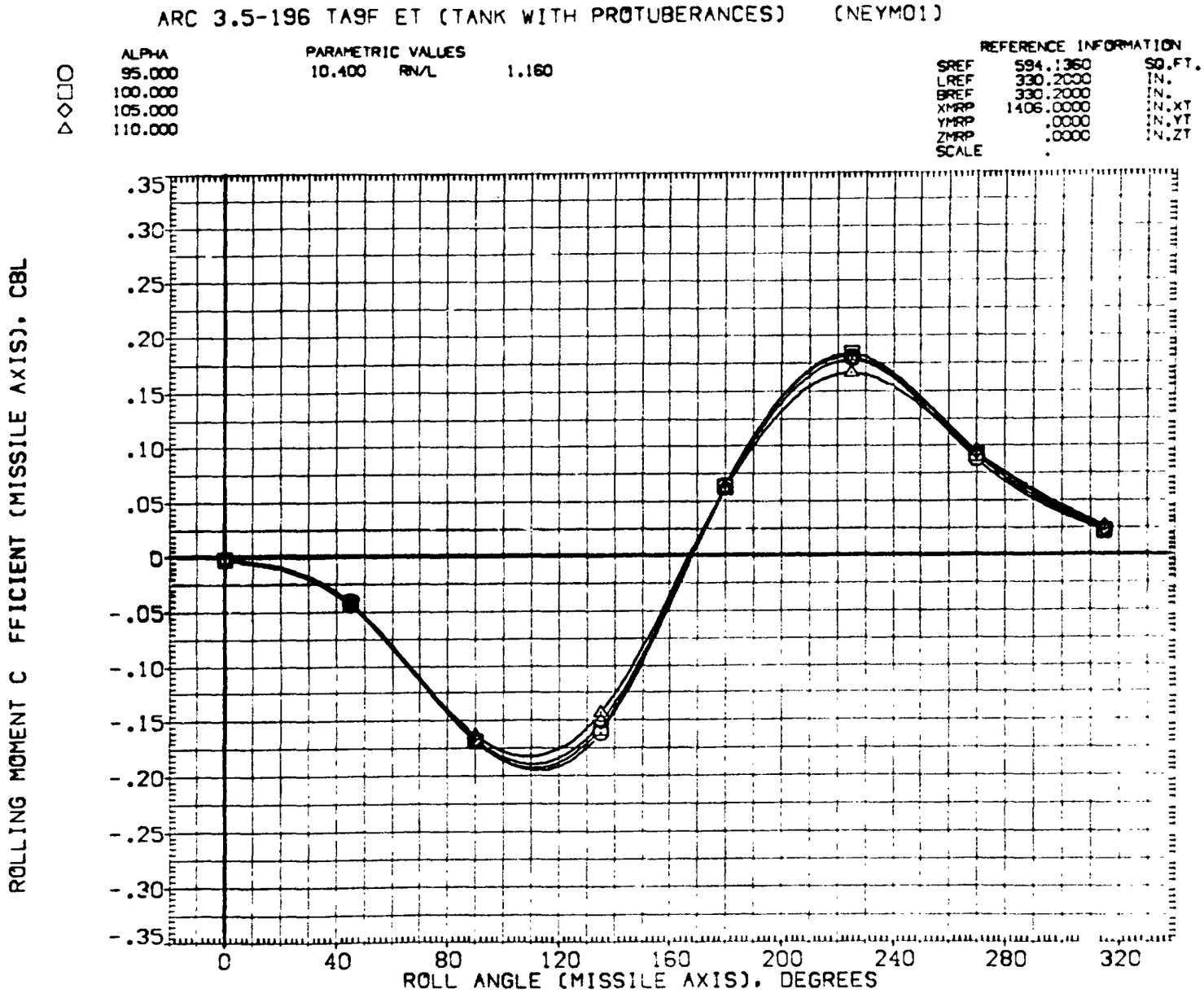

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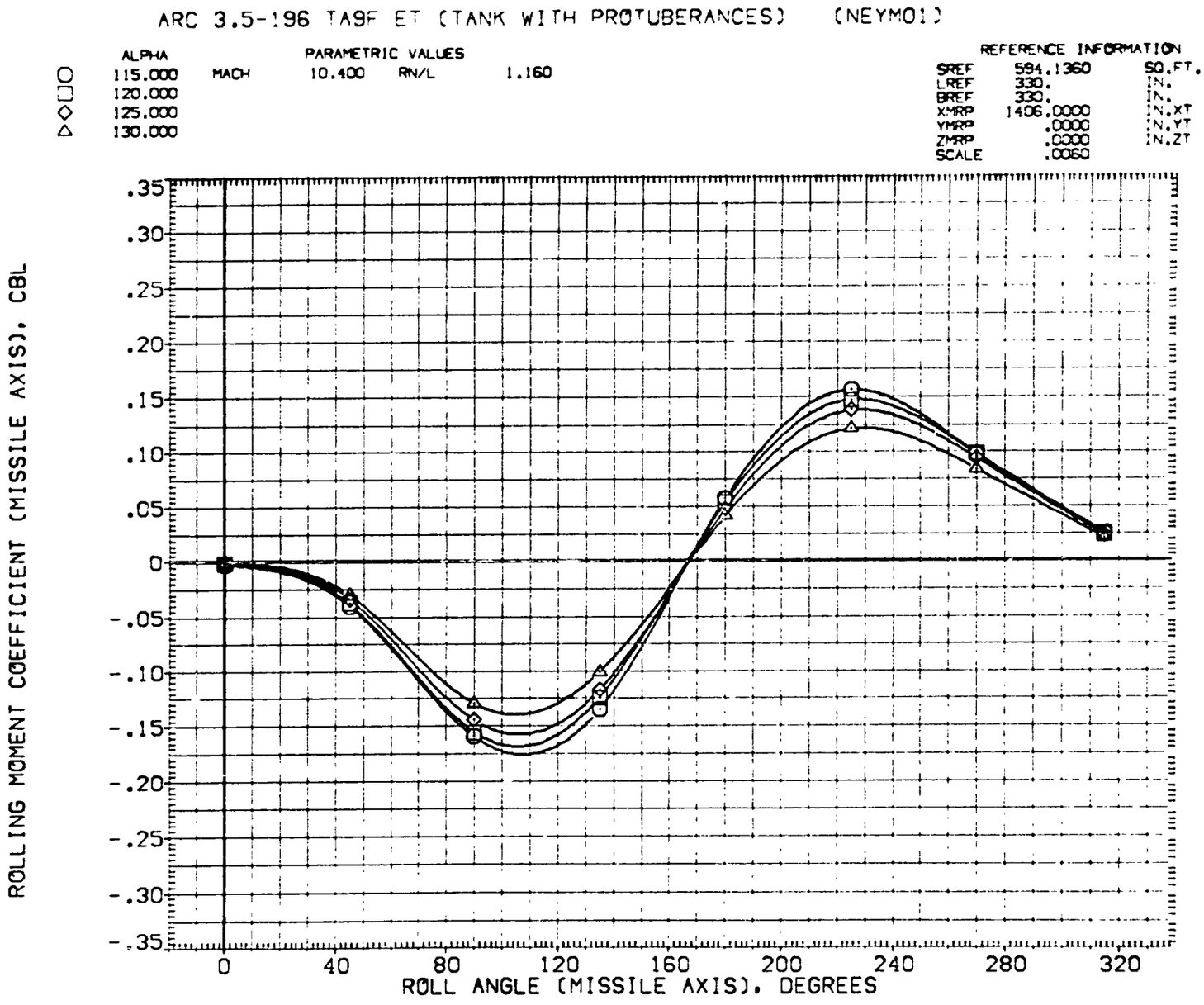

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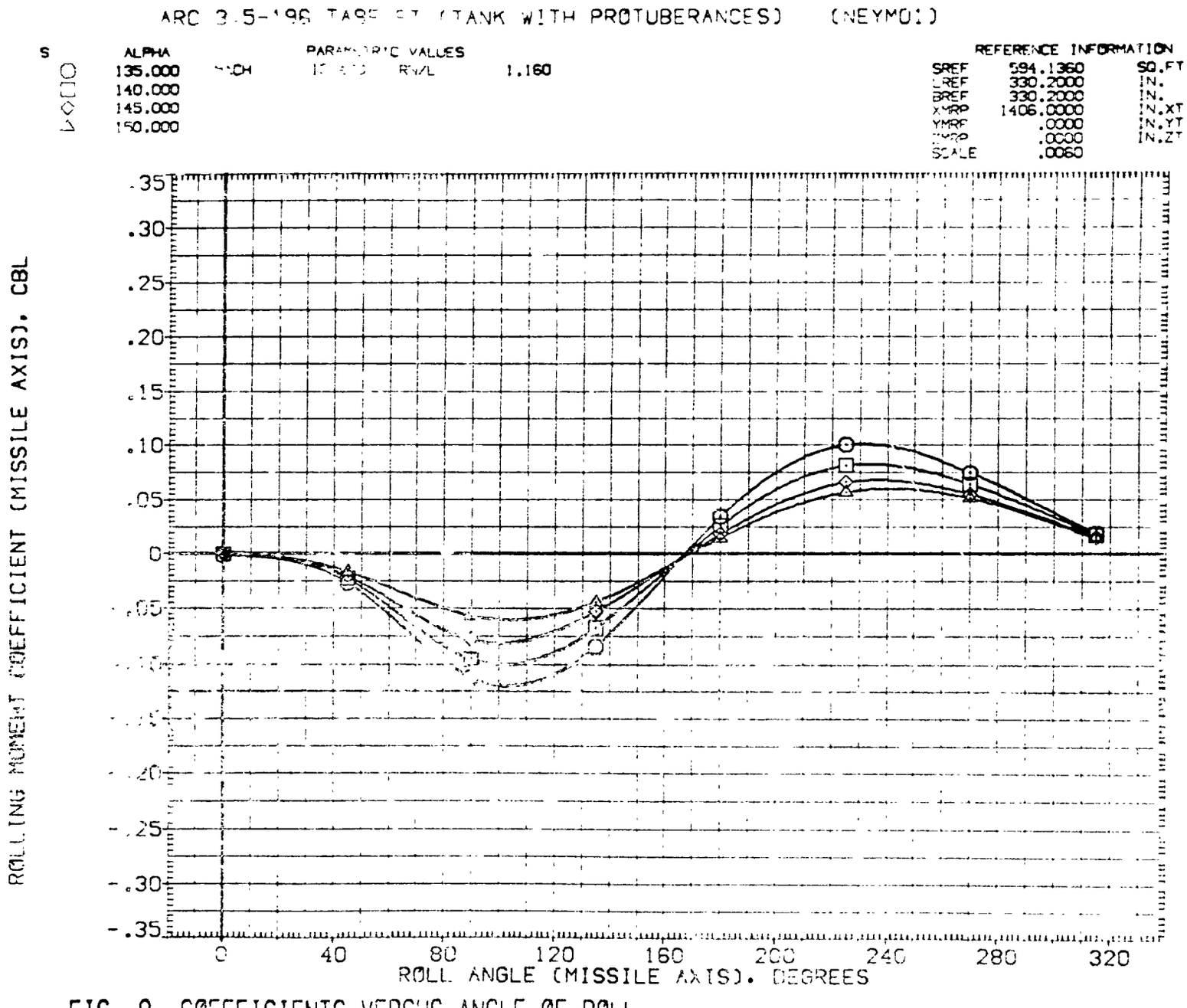

FIG. 9 COEFFICIENTS VERSUS ANGLE OF ROLL

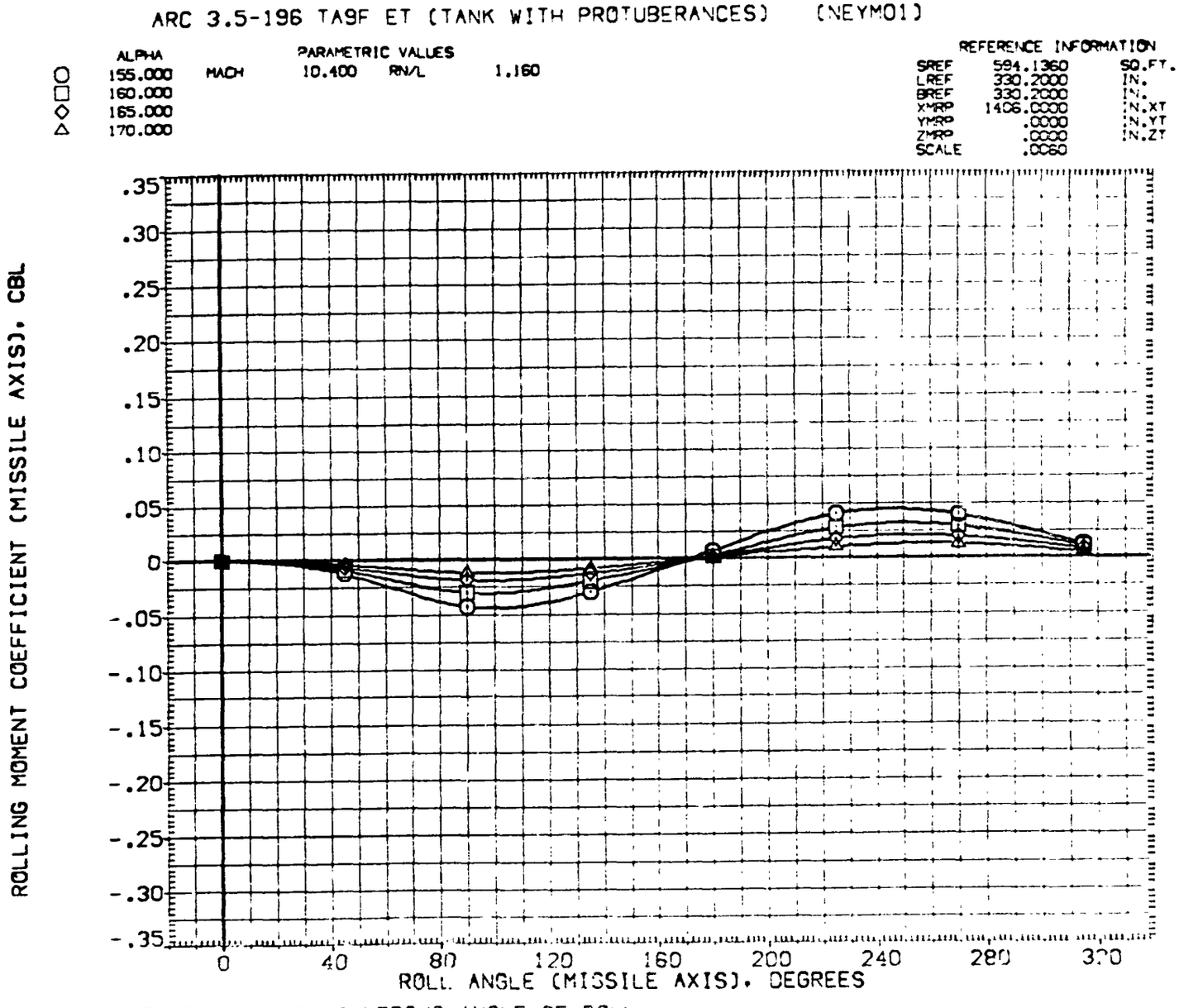

FIG. 9 COEFFICIENTS VERSUS ANGLE OF ROLL

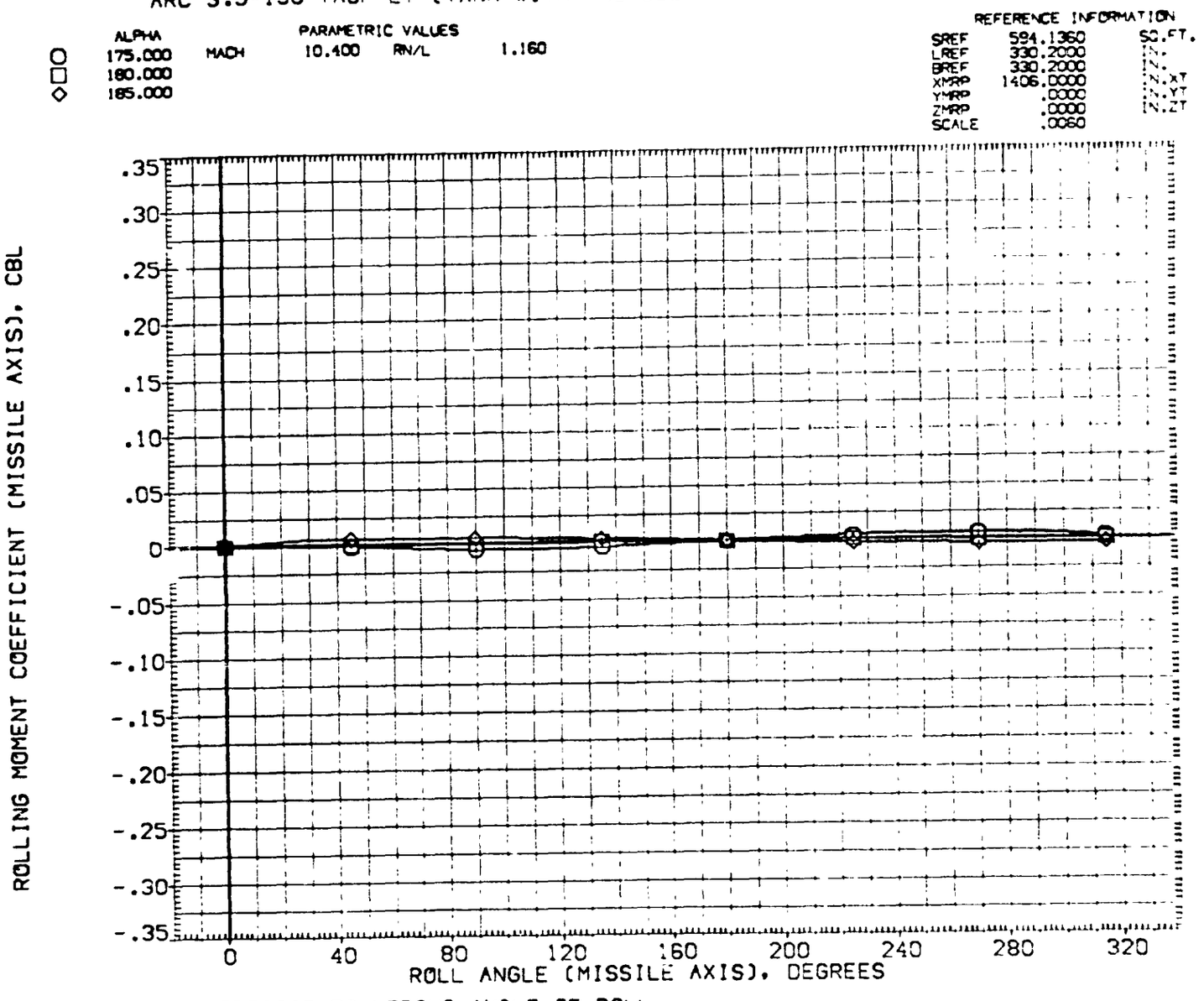

FIG. 9 COEFFICIENTS VERSUS ANGLE OF ROLL

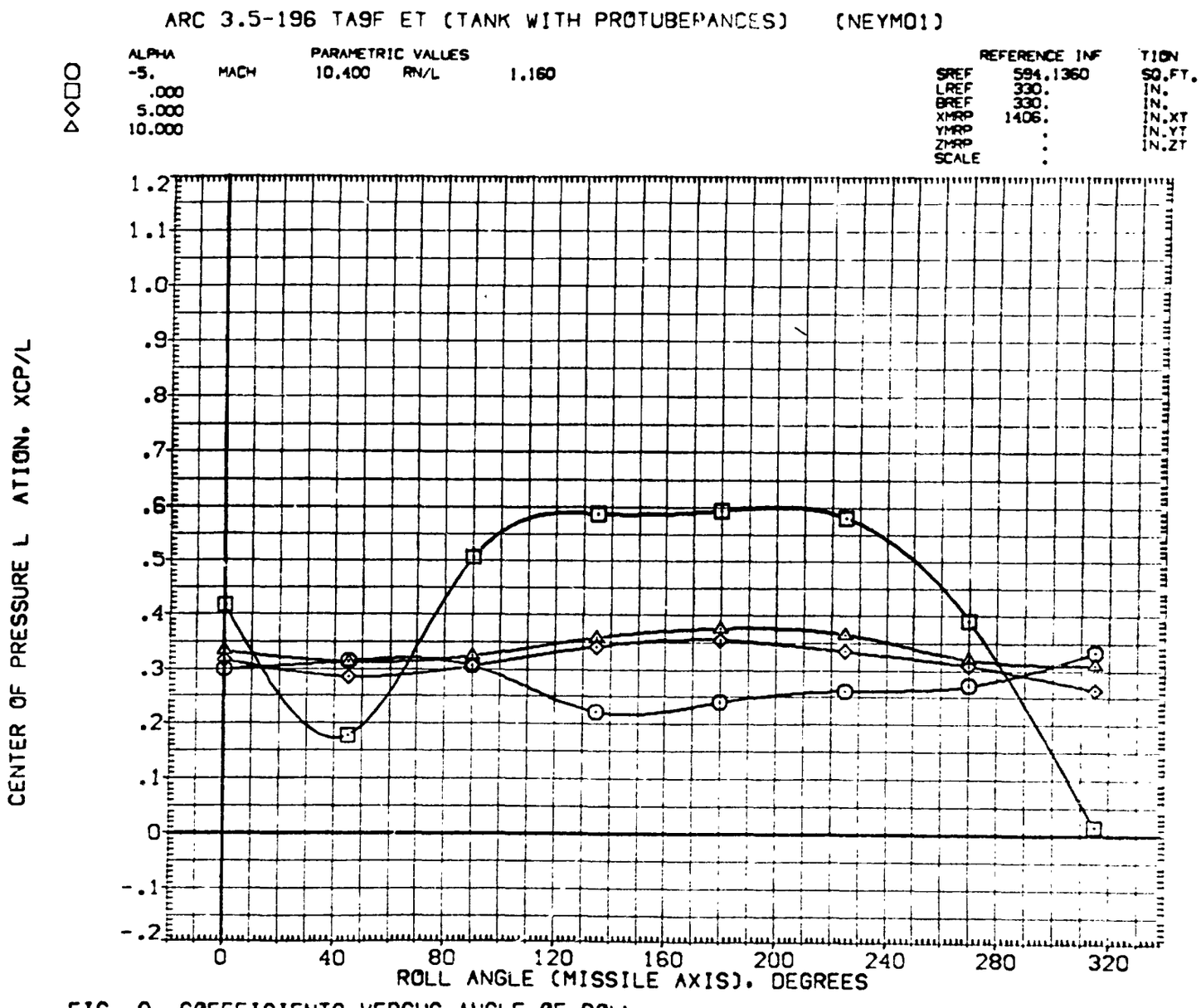

FIG. 9 COEFFICIENTS VERSUS ANGLE OF ROLL

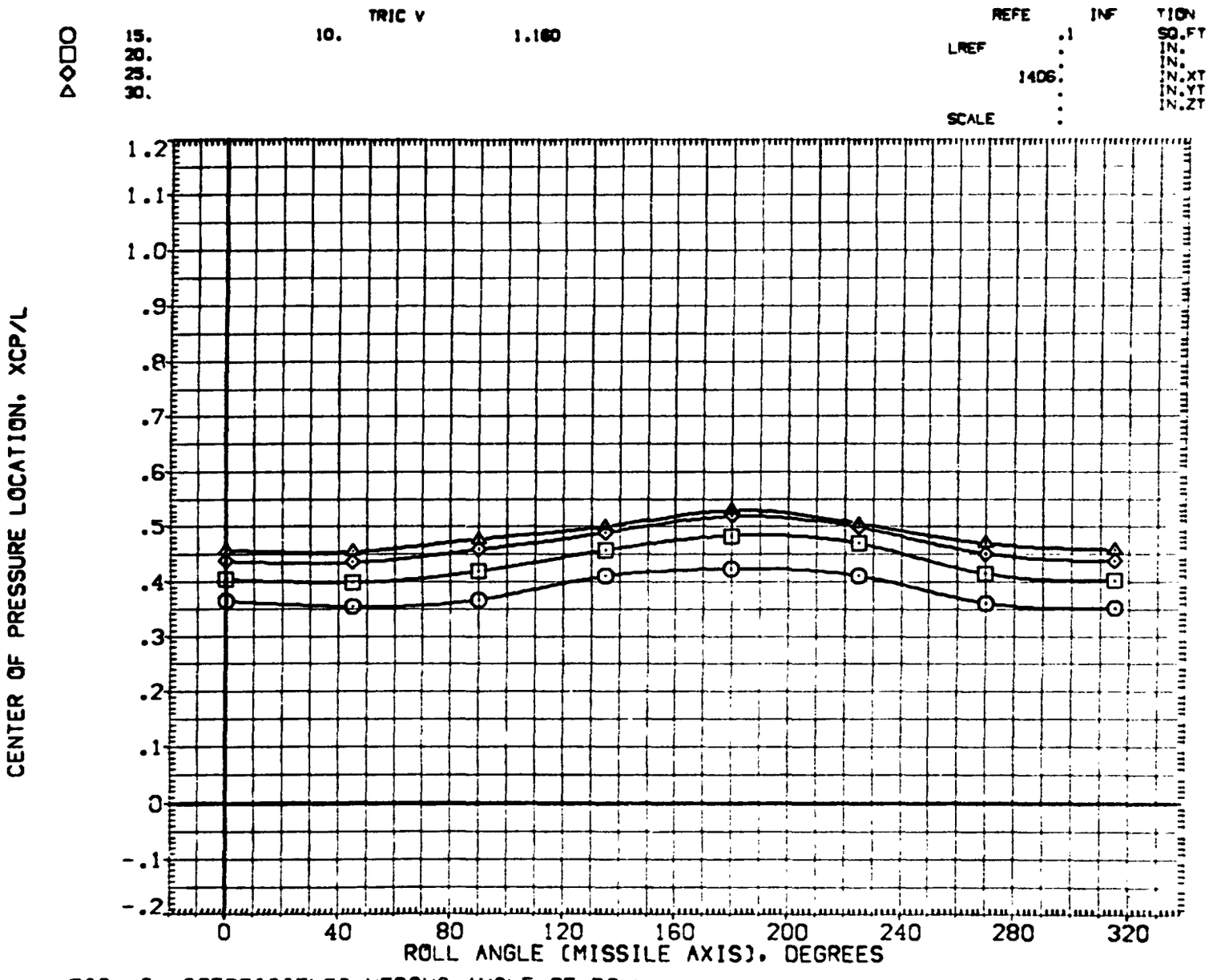

FIG. 9 COEFFICIENTS VERSUS ANGLE OF ROLL

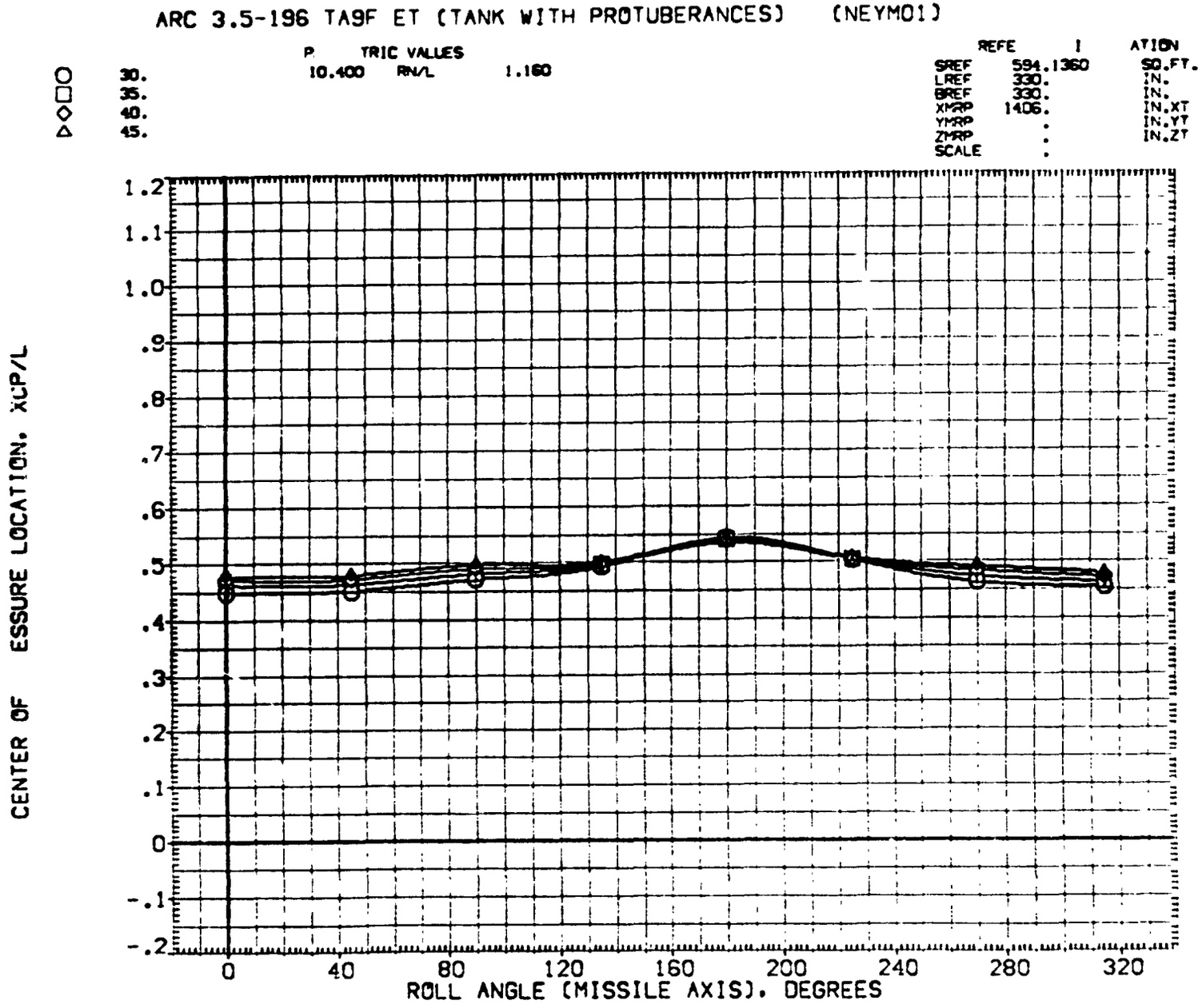

FIG. 9 COEFFICIENTS VERSUS A LE OF ROLL

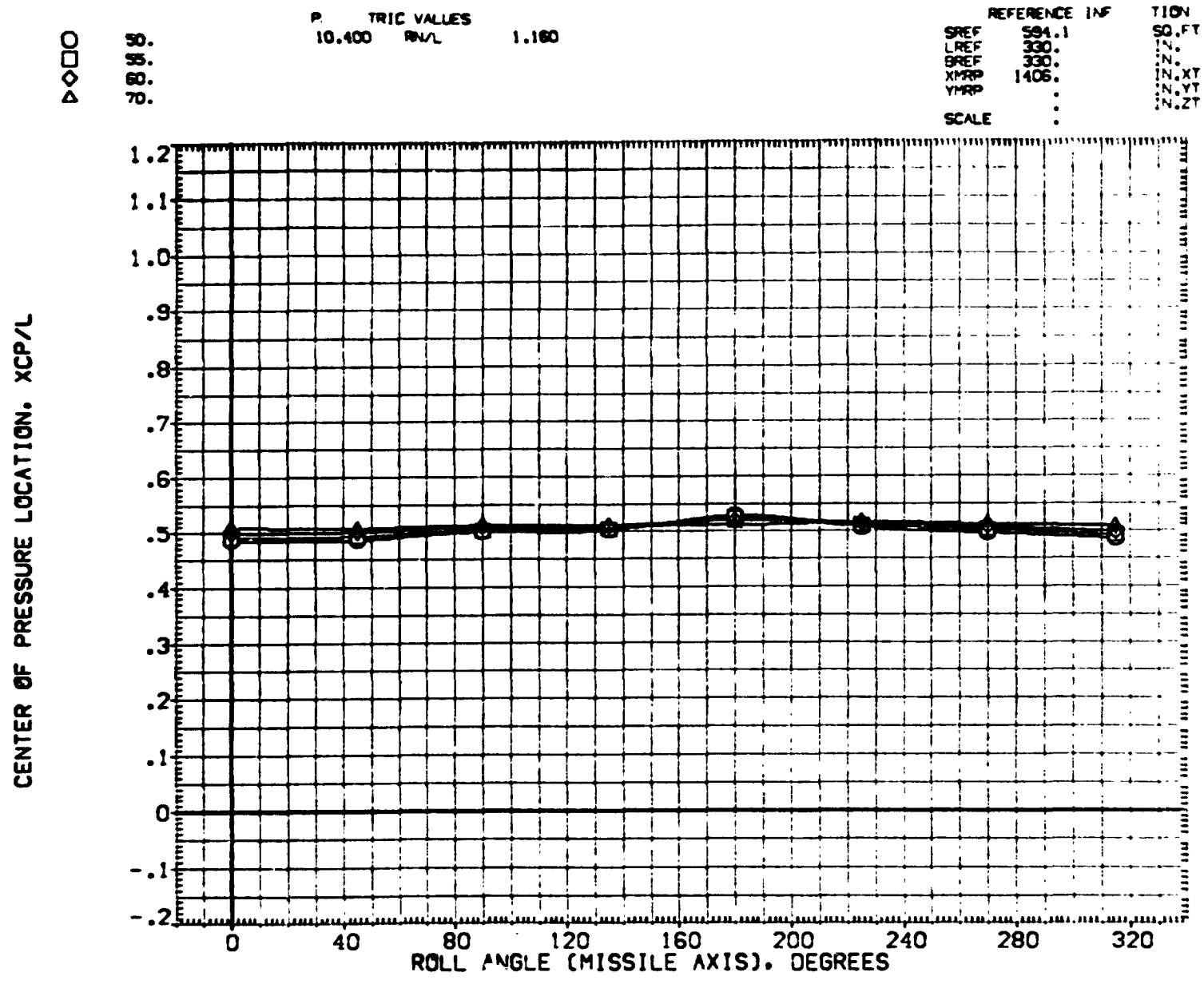

FIG. 9 C FFICIENTS VE US ANGLE OF ROLL

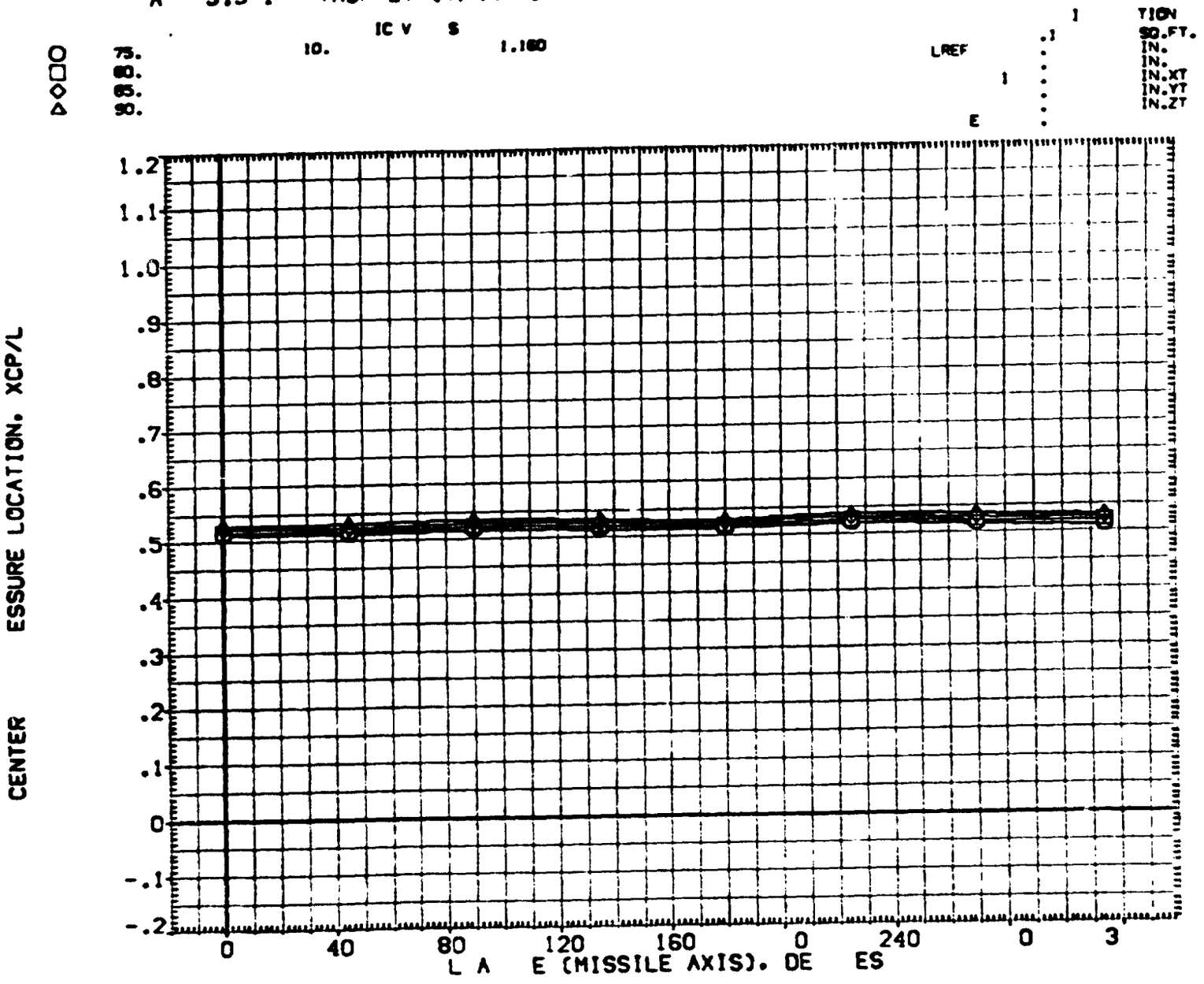

FIG. 9 COEFFICIENTS VERSUS ANGLE OF ROLL

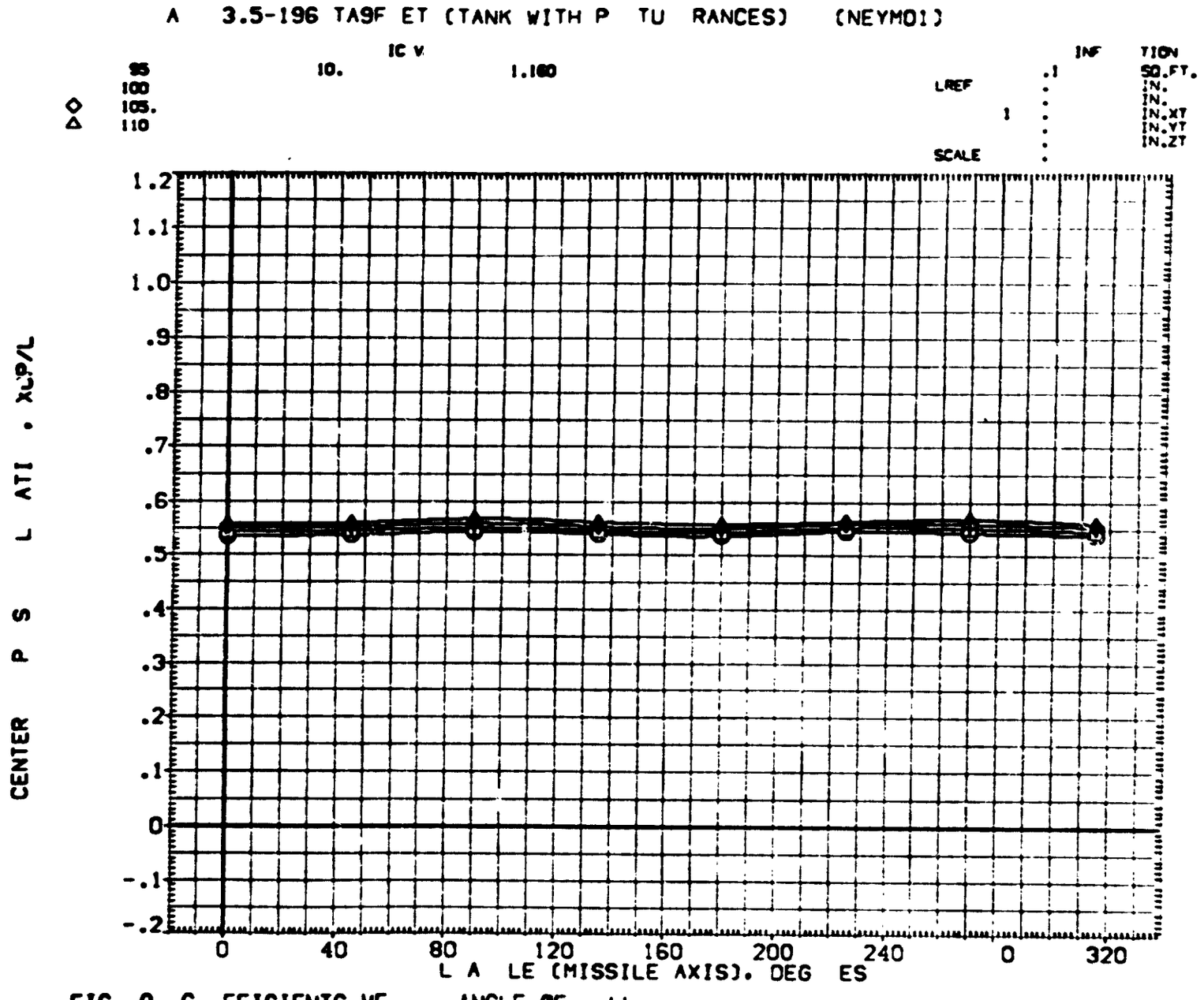

FIG. 9 C FFICIENTS VE A'GLE OF LL

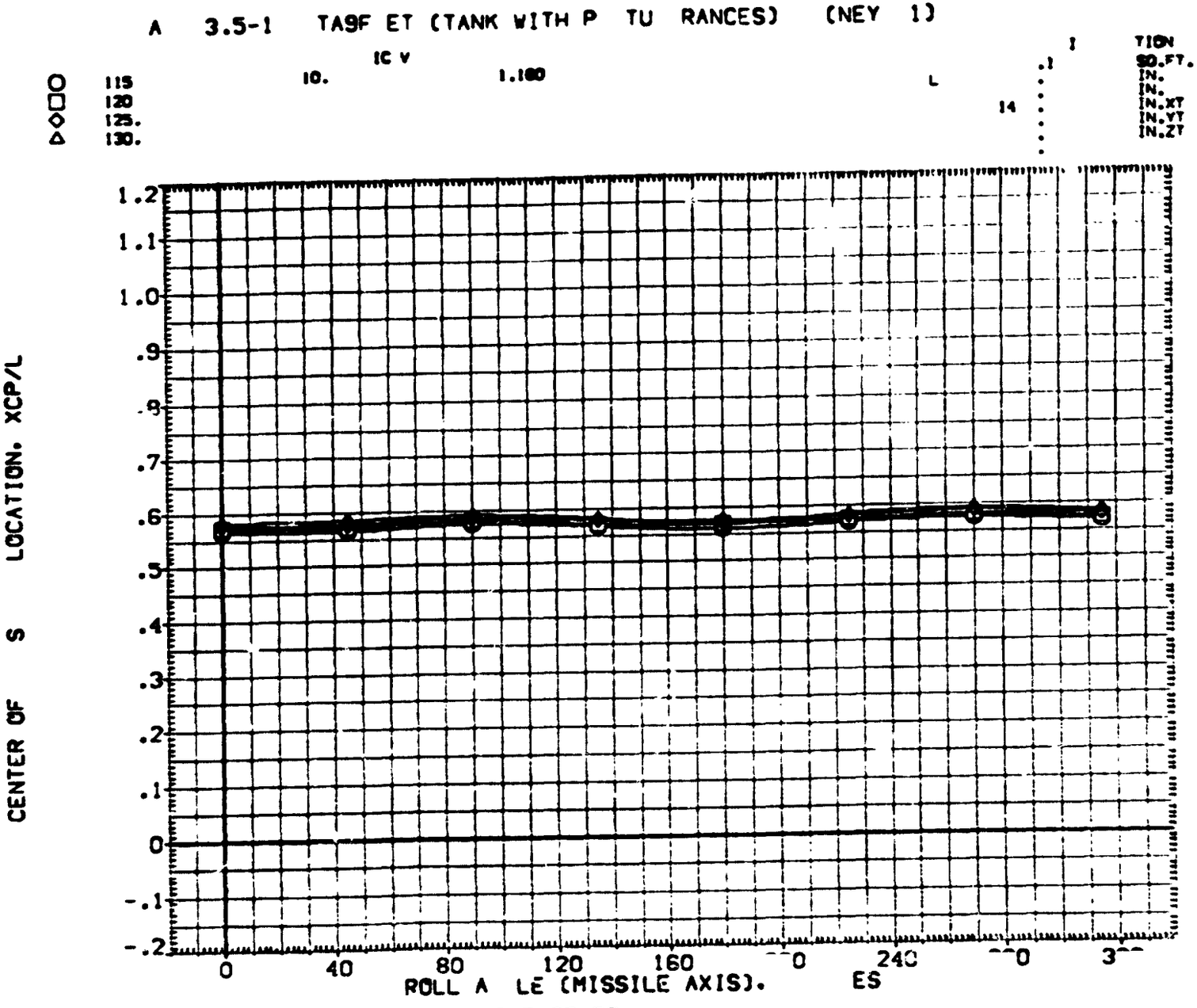

FIG. 3 C FFICIENTS VE ANGLE OF ROLL

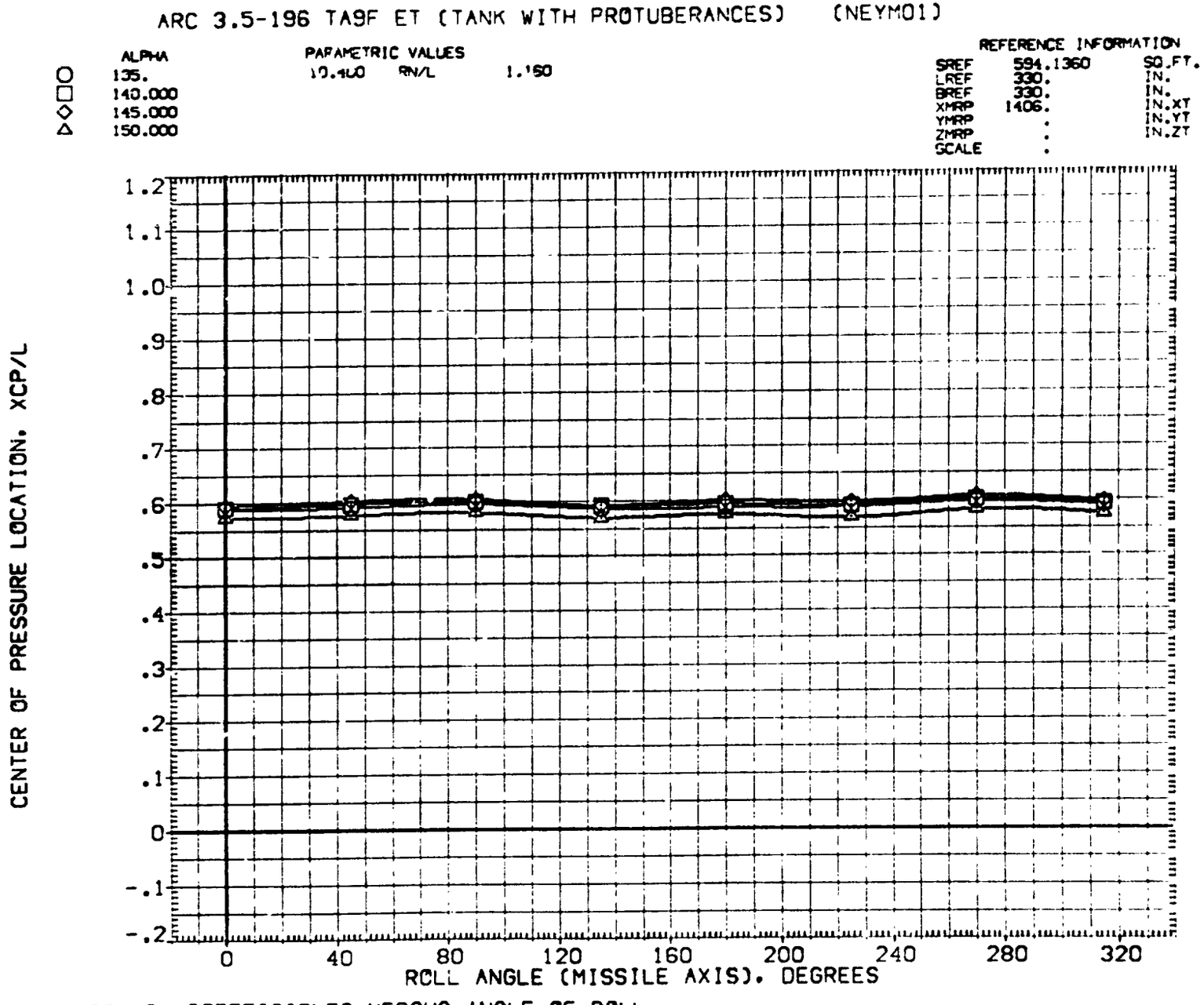

FIG. 9 COEFFICIENTS VERSUS ANGLE OF ROLL

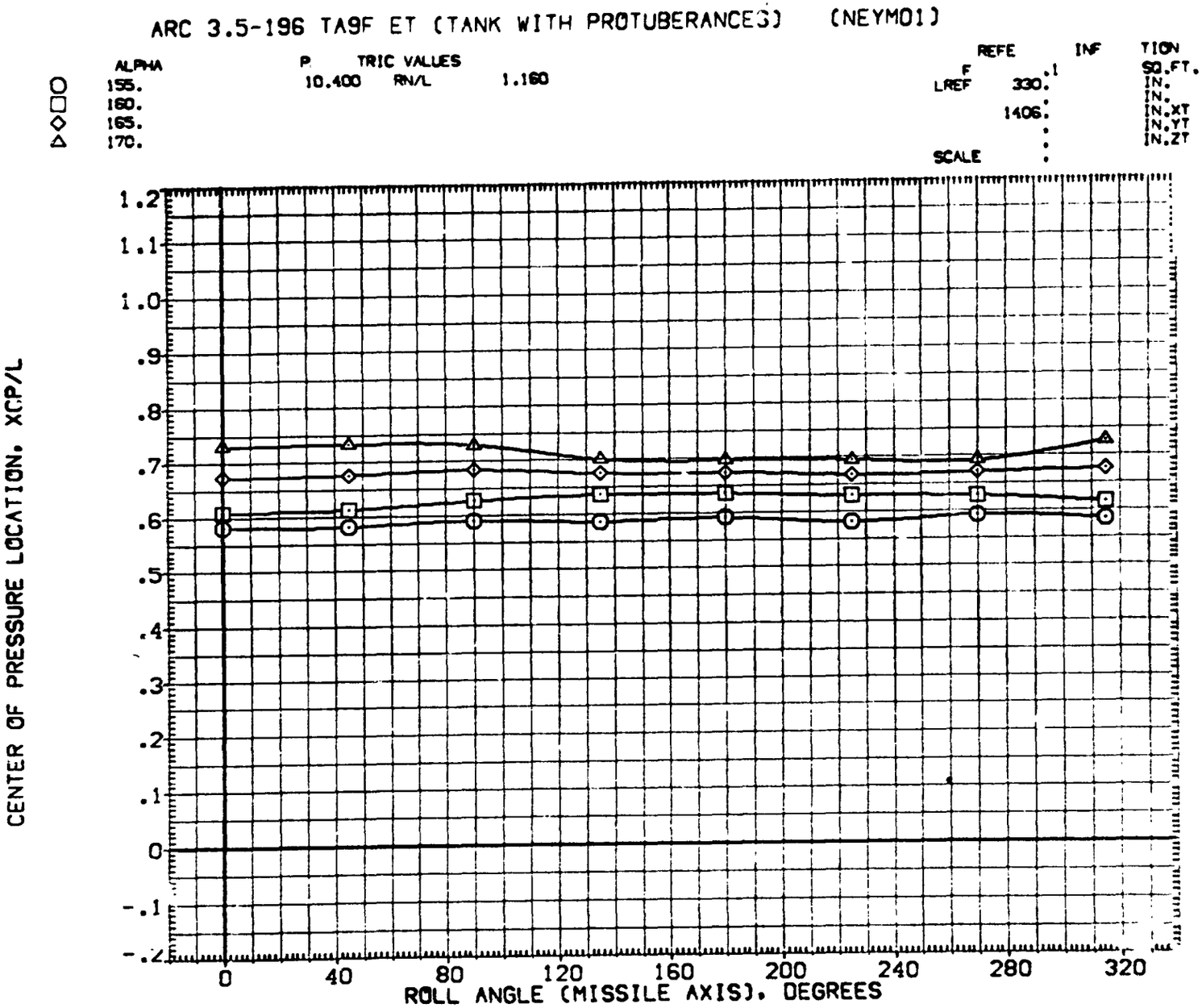

FIG. 9 COEFFICIENTS VERSUS ANGLE OF ROLL

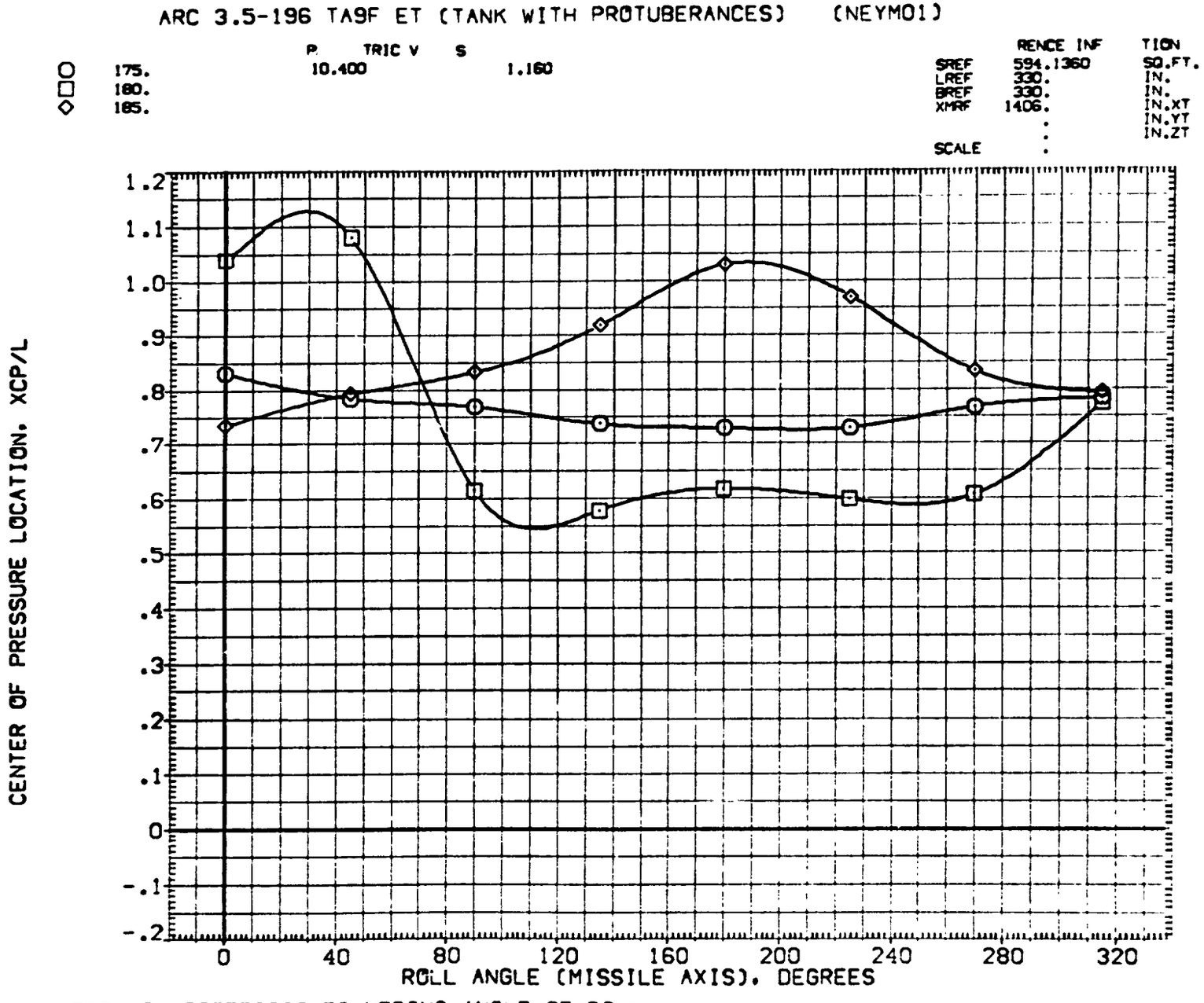

FIG. 9 COEFFICIENTS VERSUS ANGLE OF ROLL

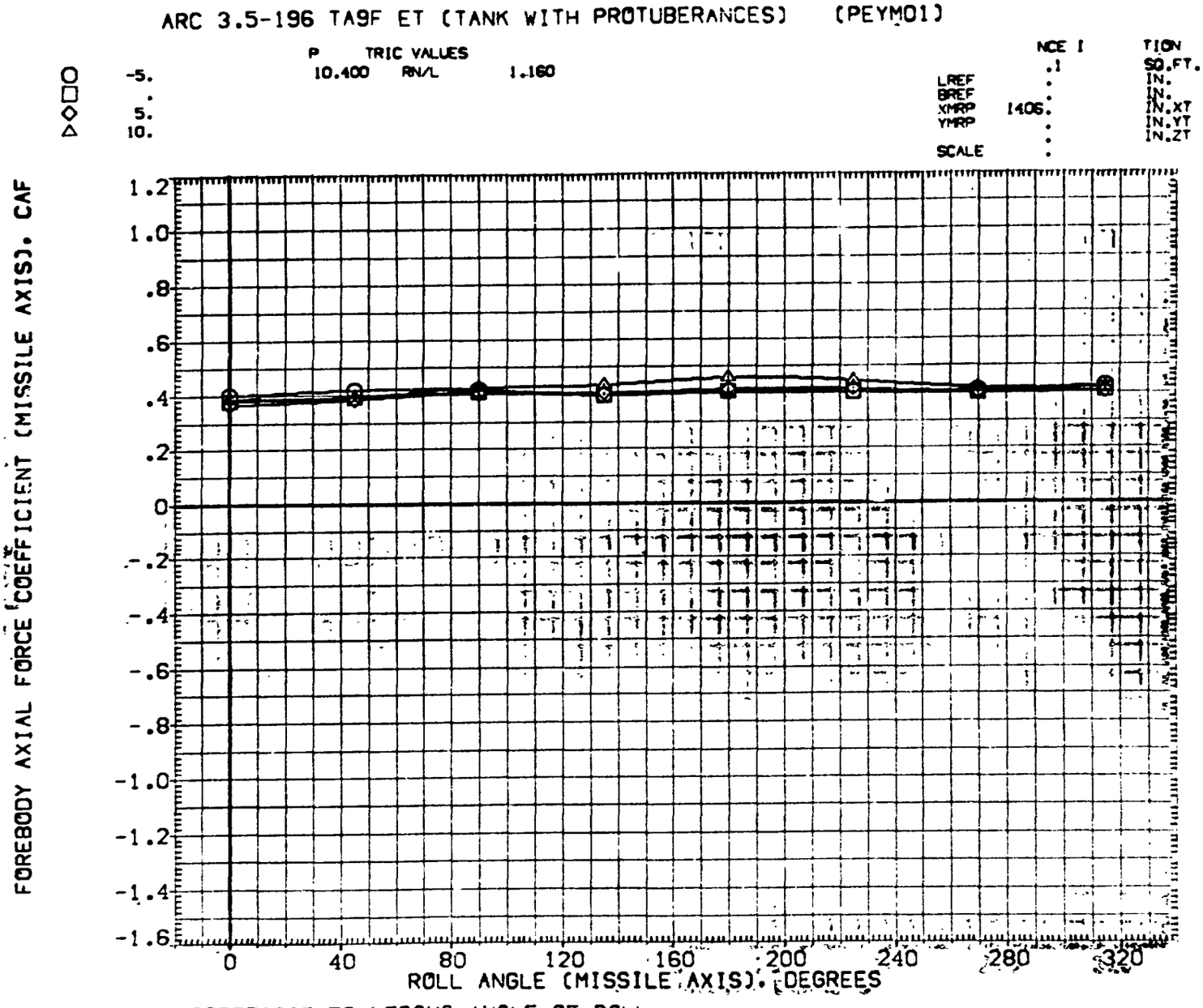

FIG. 9 COEFFICIENTS VERSUS ANGLE OF ROLL

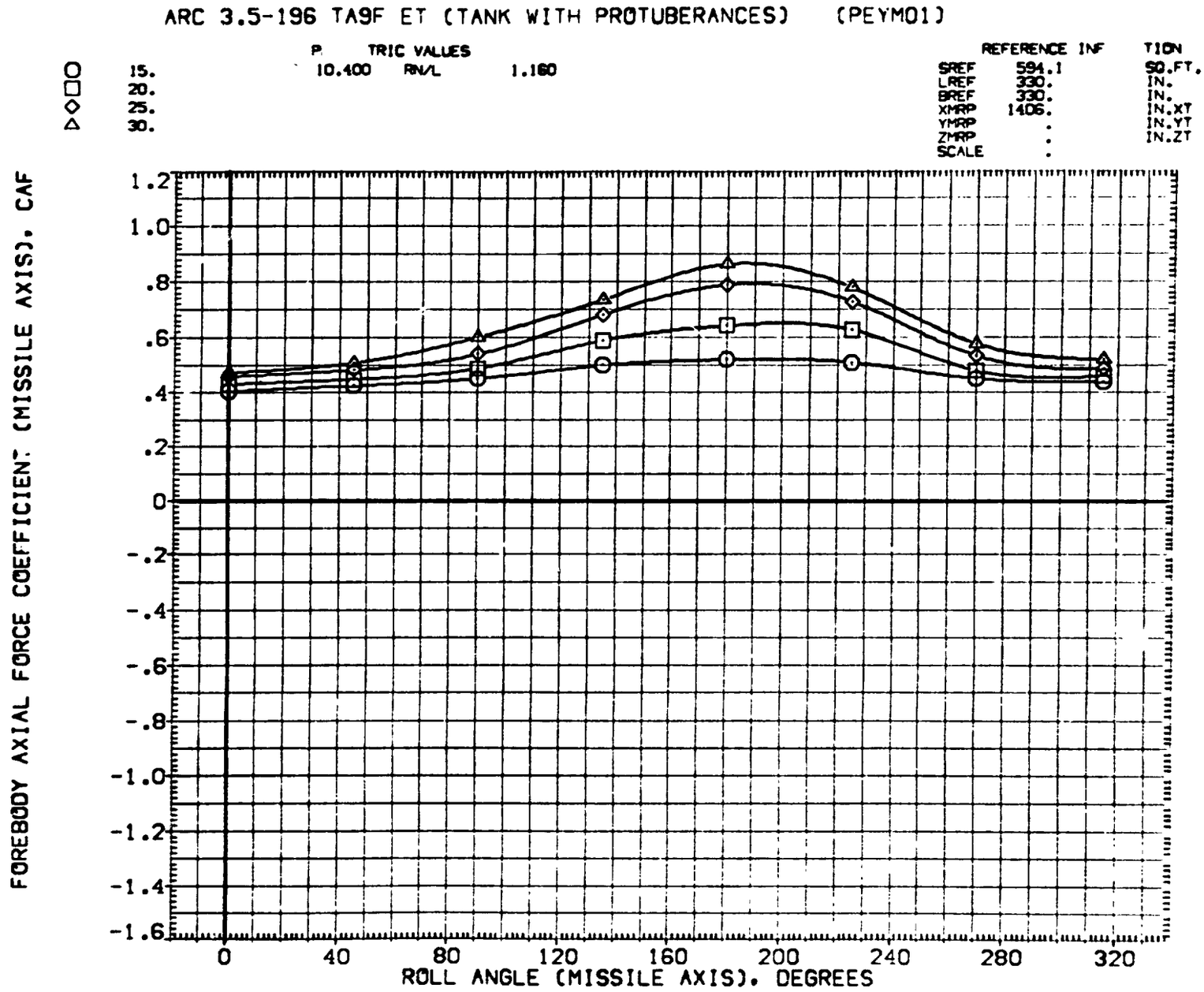

FIG. 9 COEFFICIENTS VERSUS ANGLE OF ROLL

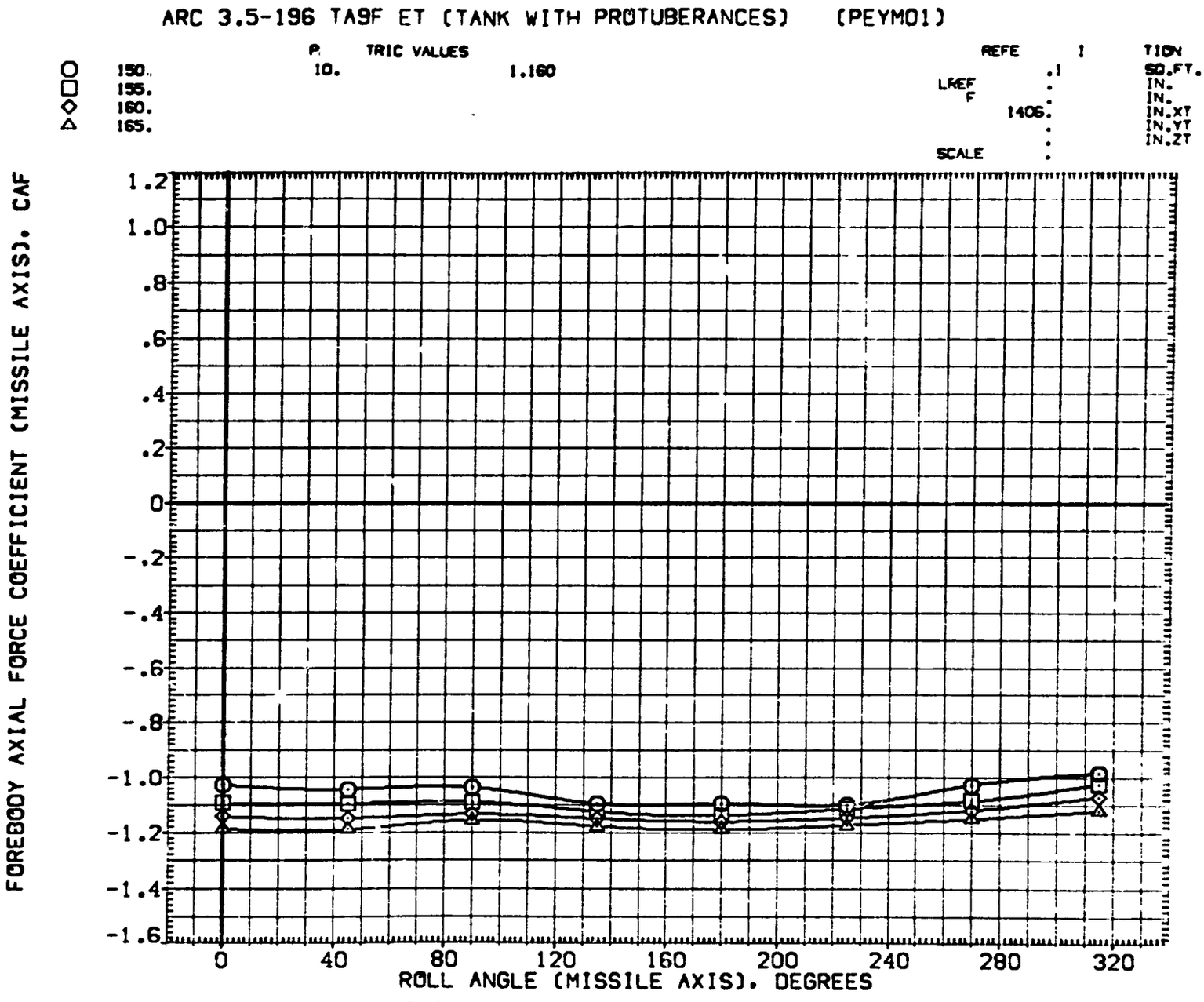

FIG. 9 COEFFICIENTS VERSUS ANGLE OF ROLL

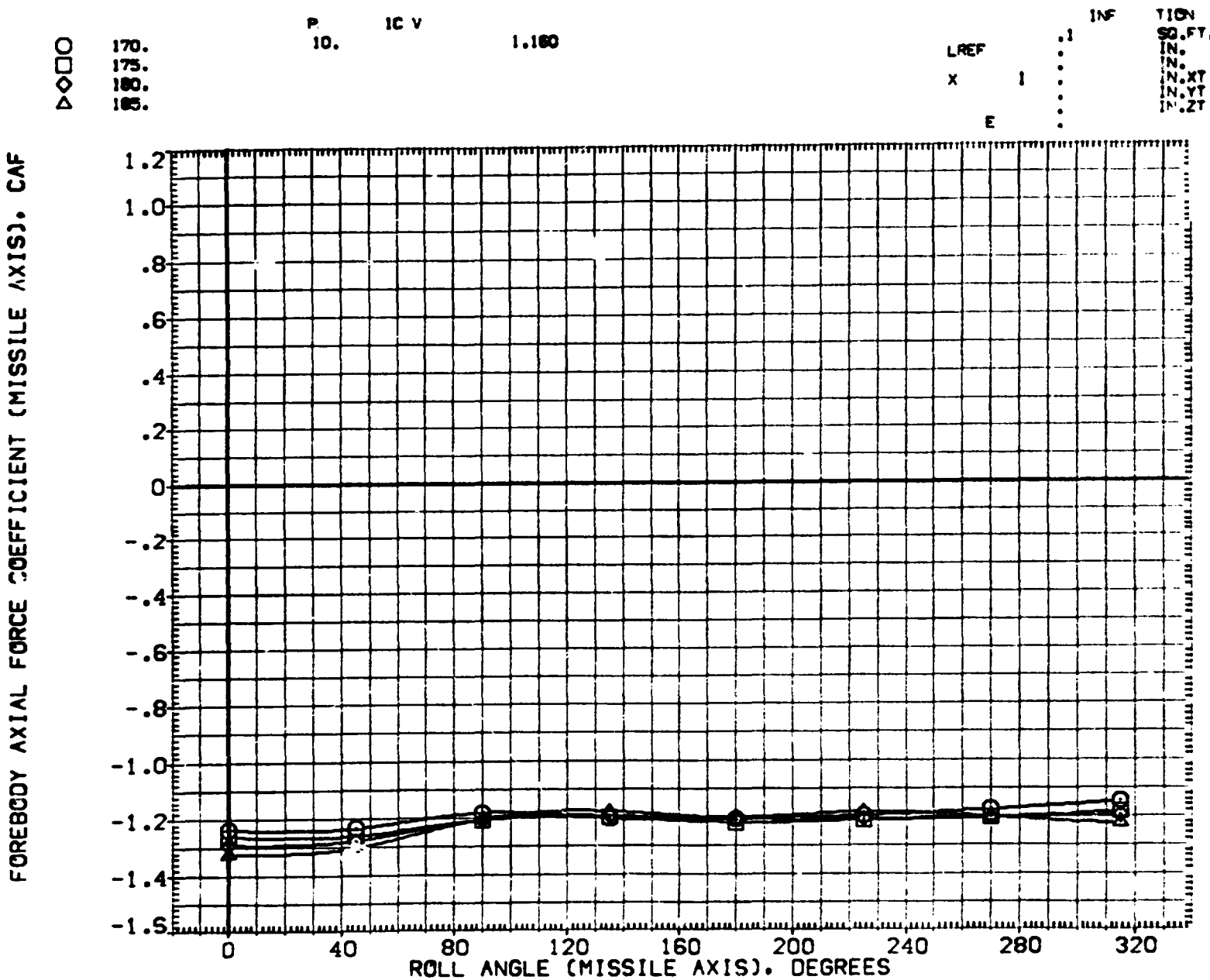

FIG. 9 COEFFICIENTS VERSUS ANGLE OF ROLL

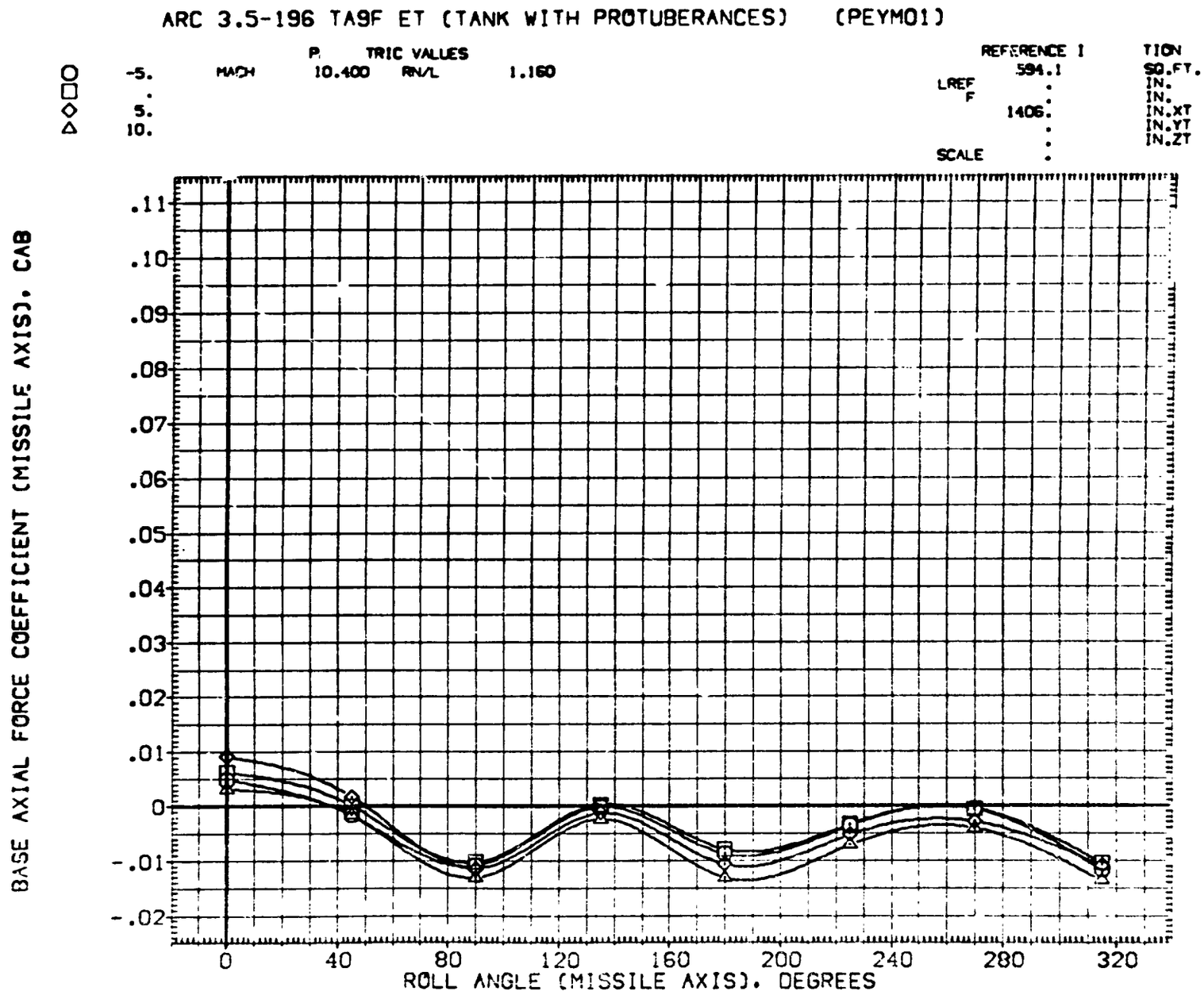

FIG. 9 COEFFICIENTS VERSUS ANGLE OF ROLL

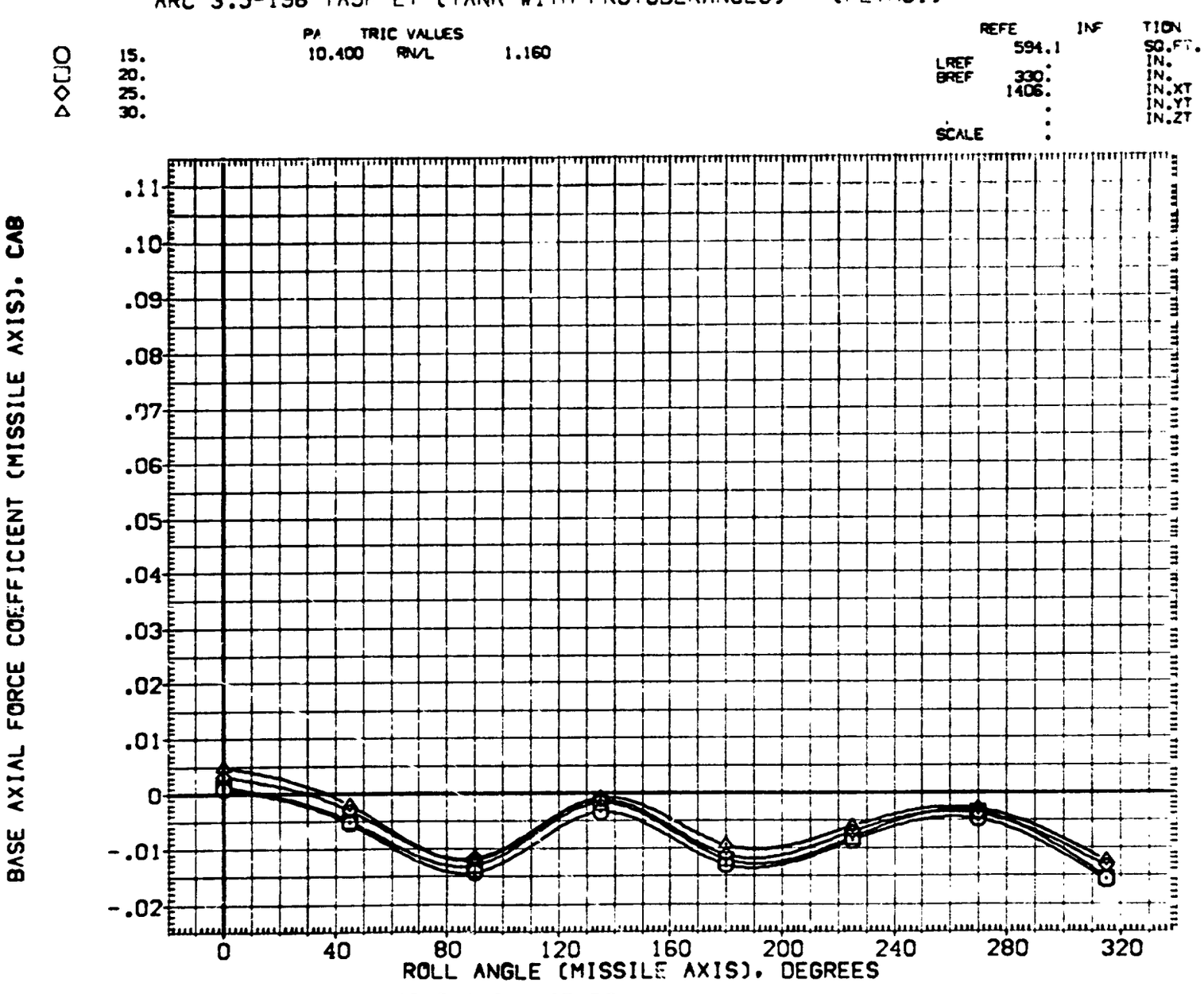

FIG. 9 COEFFICIENTS VERSUS ANGLE OF ROLL

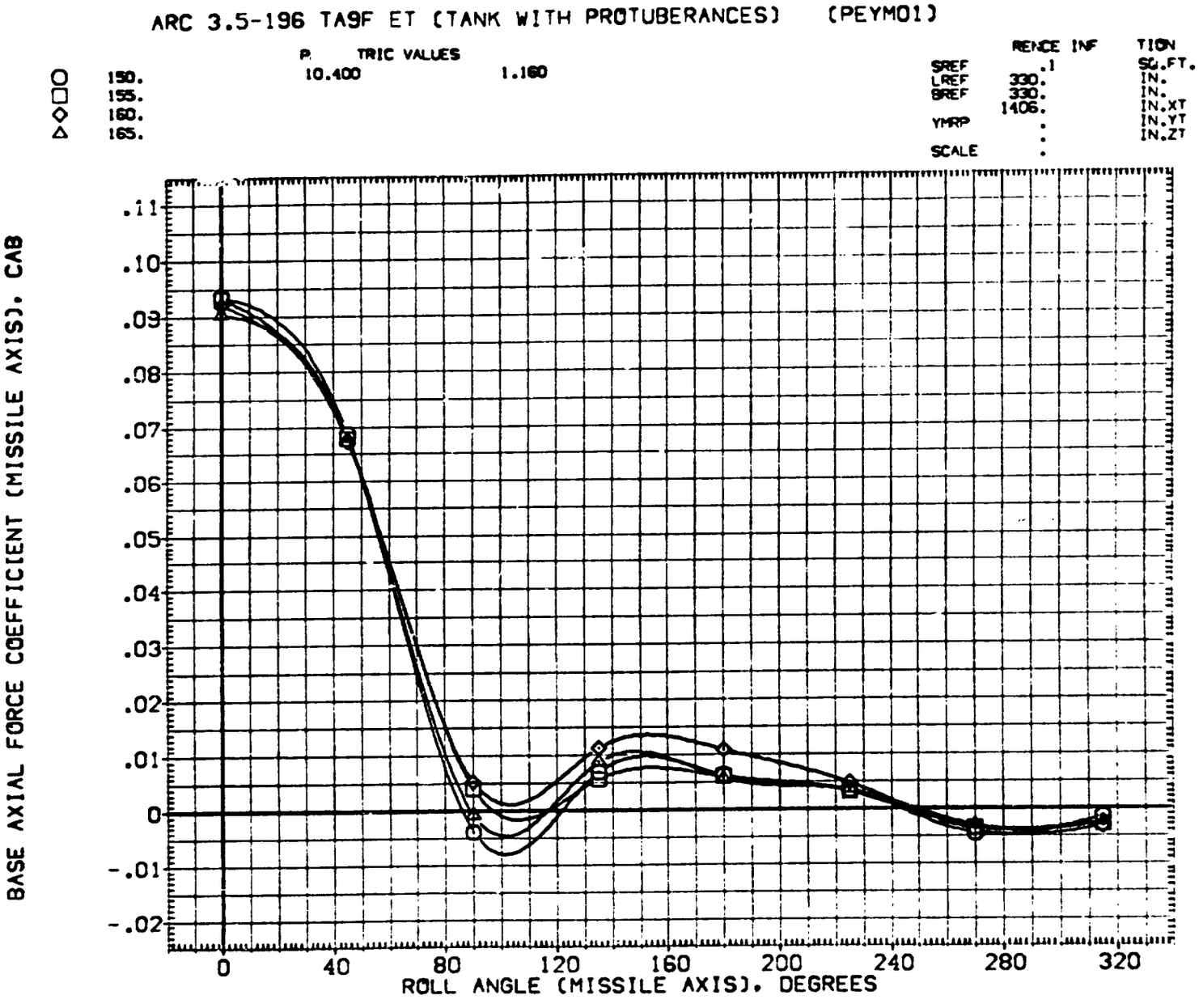

FIG. 9 COEFFICIENTS VERSUS ANGLE OF ROLL

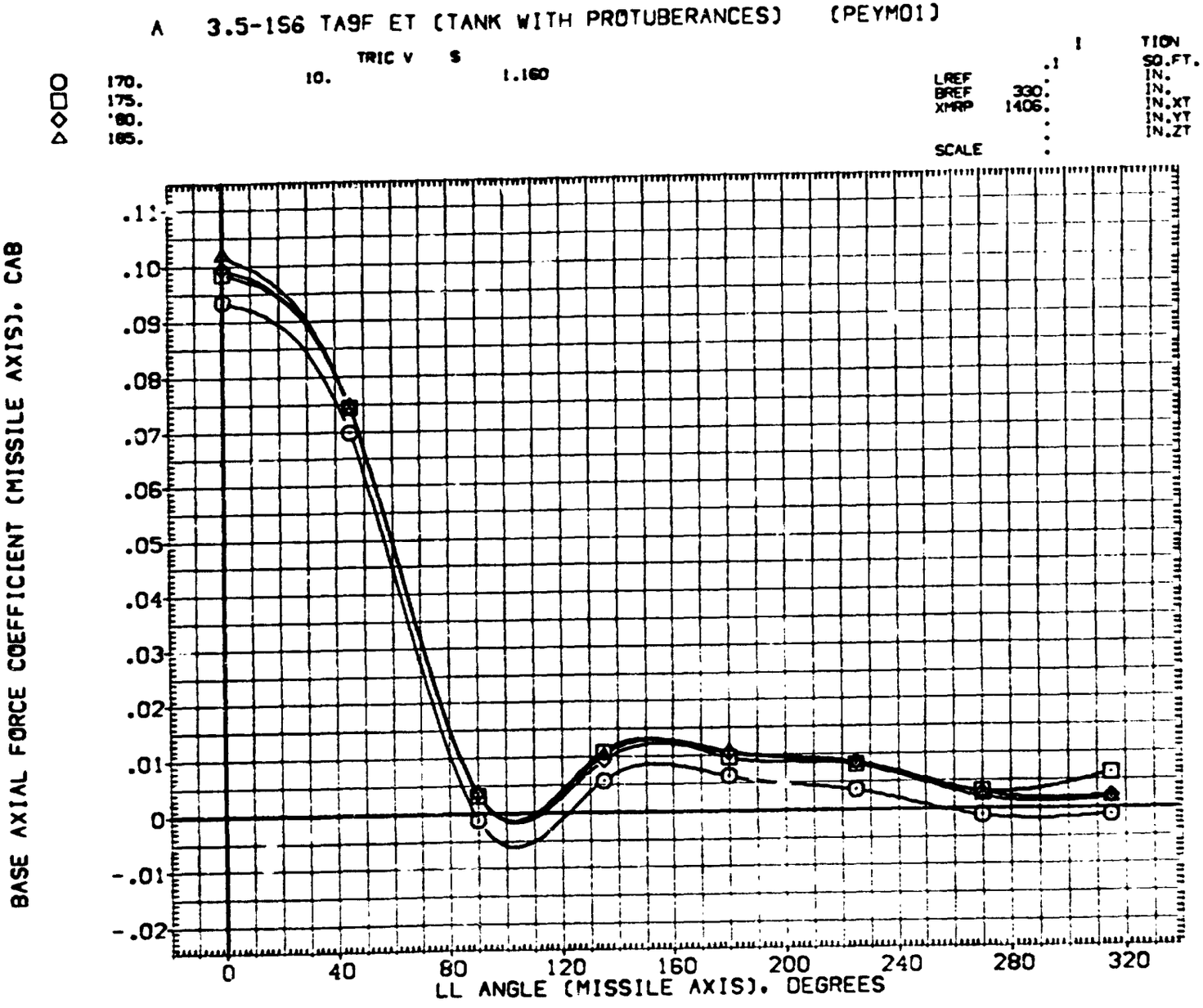

FIG. 9 COEFFICIENTS VERSUS ANGLE OF ROLL

DATA SET I TION DE IPTION
(DEVMOI) ARC 3.5-196 TASF ET (TANK WITH) 10.400 1.160
(RE) 3.5-196 TASF ET (IC TANK) 10.400 1.160

INF ATION
SREF 594.1360 SQ.FT.
LREF . IN.
F . IN.
1406. IN.XT
. IN.YT
. IN.ZT
SCALE .

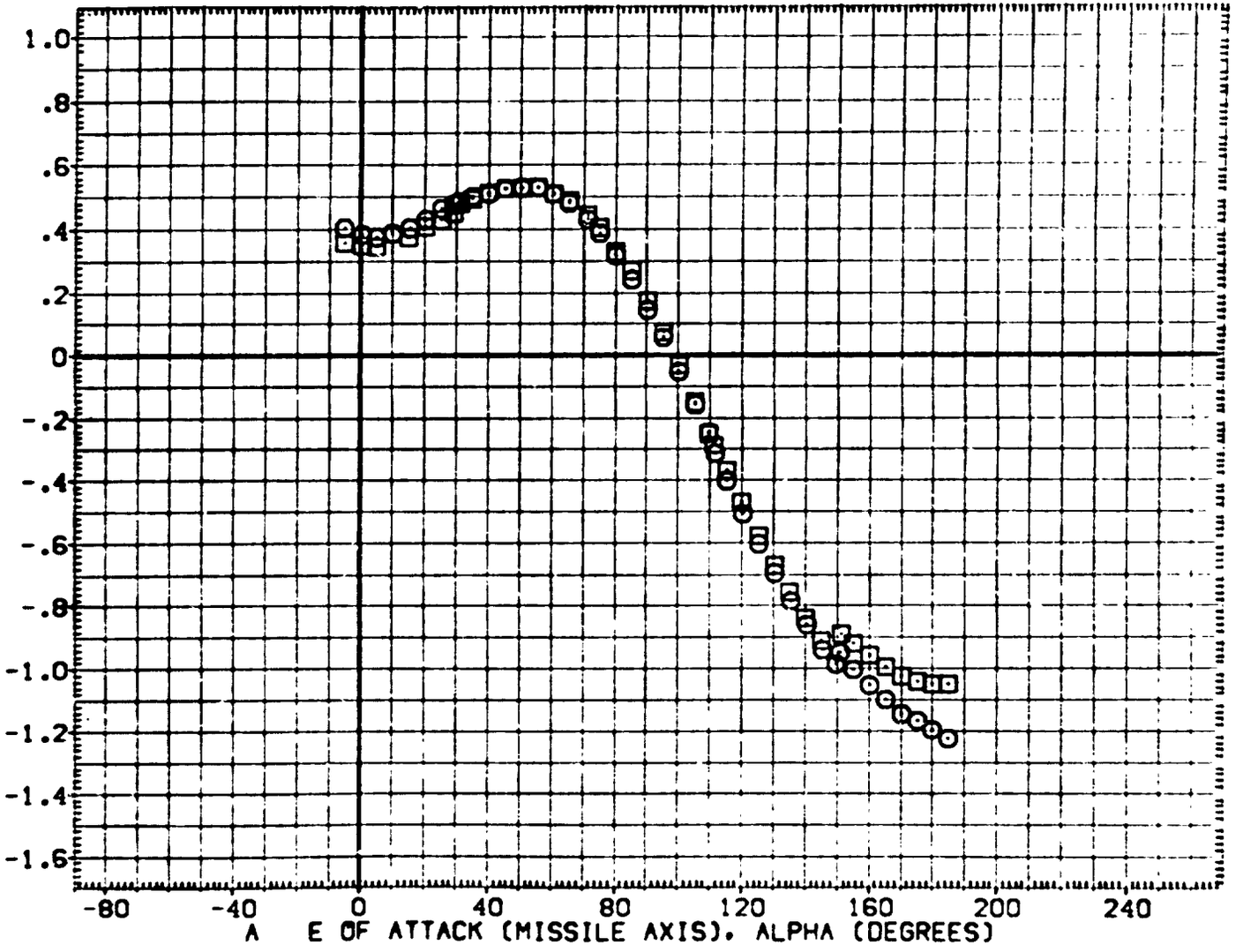

FIG. 10 BASIC TANK VERSUS TANK WITH PROTUBERENCES

(A)PHI = .00

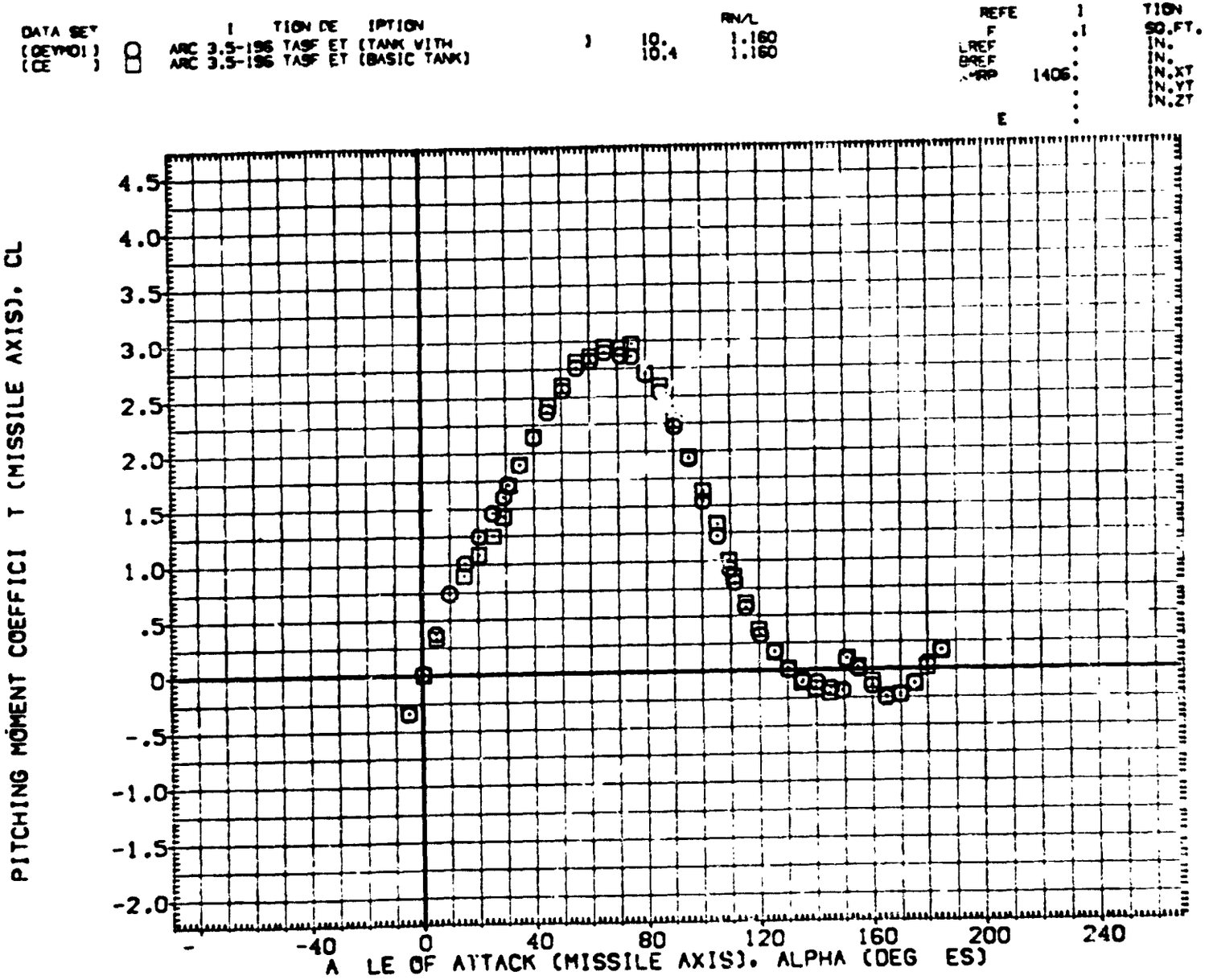

FIG. 10 BASIC TANK VERSUS TANK WITH PROTUBERENCES

(A)PHI = .00

DATA SET		TION	IPTION		MACH	RN/L		INF	TION
(REYNOI)	ARC 3.5-196 T		ET (TANK WITH	)	10.	1.160	F	.1	SO.FT.
(CE)	ARC 3.5-196 T		ET (IC TANK)		10.400	1.160	LREF	.	IN.
								330.	IN.
								1406.	IN.XT
								.	IN.YT
								.	IN.ZT

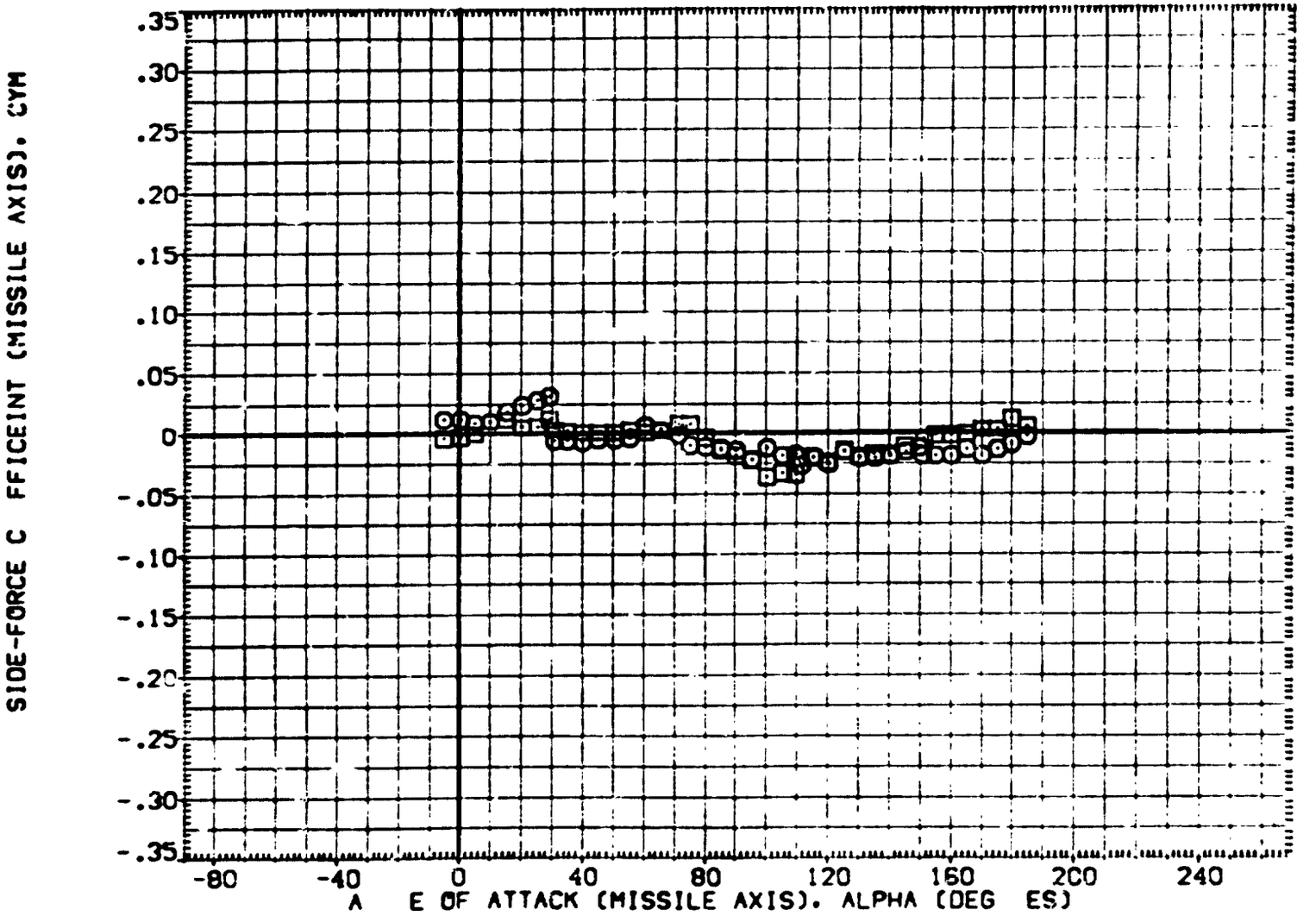

FIG. 10 BASIC TA VE S TANK WITH PROTUBERENCES

(A)=AI = .00

C-3

DATA SET		I	TION	IPTION			RN/L	
(1)	8		3.5-196 TASF ET (TANK WITH	T	S)	10.400	1.160
(CE)	8	ARC	3.5-196 TASF ET (BASIC TANK)			10.400	1.160

REFE	INF	TION
	594.1	SQ.FT.
LREF	330.	IN.
BREF	330.	IN.
	1406.	IN.XT
	:	IN.YT
	:	IN.ZT
SCALE	:	

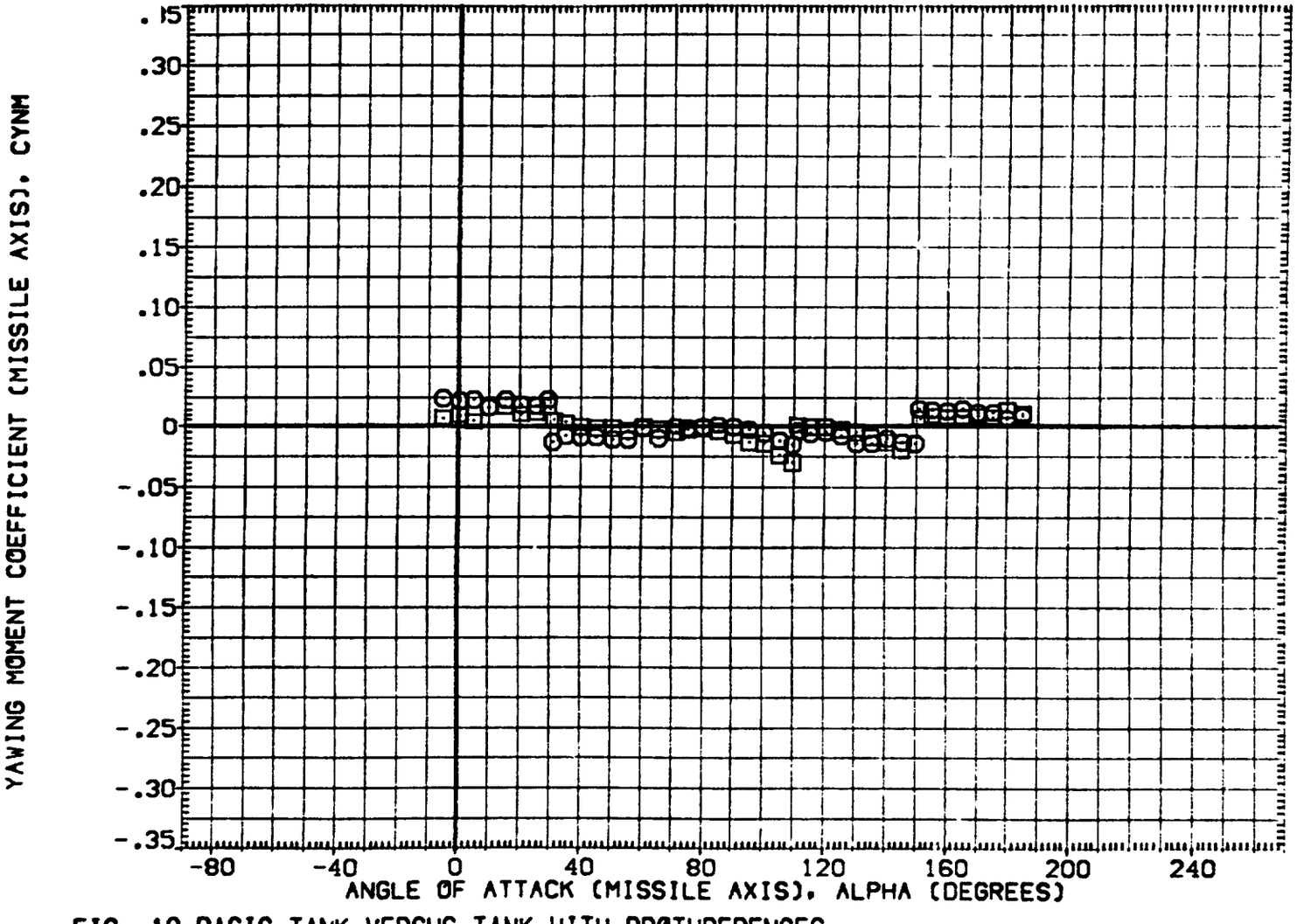

FIG. 10 BASIC TANK VERSUS TANK WITH PROTUBERENCES

(A)PHI = .00

DATA I TION IPTION NCE INF TION

[1] 3.5-196 TASF ET (TANK WITH) 10.400 1.160 F .1 SQ.FT.

[ ] 3.5-196 TASF ET (IC TANK) 10. 1.160 LREF . IN.

F . IN.

1406. . IN.XT

. IN.YT

E . IN.ZT

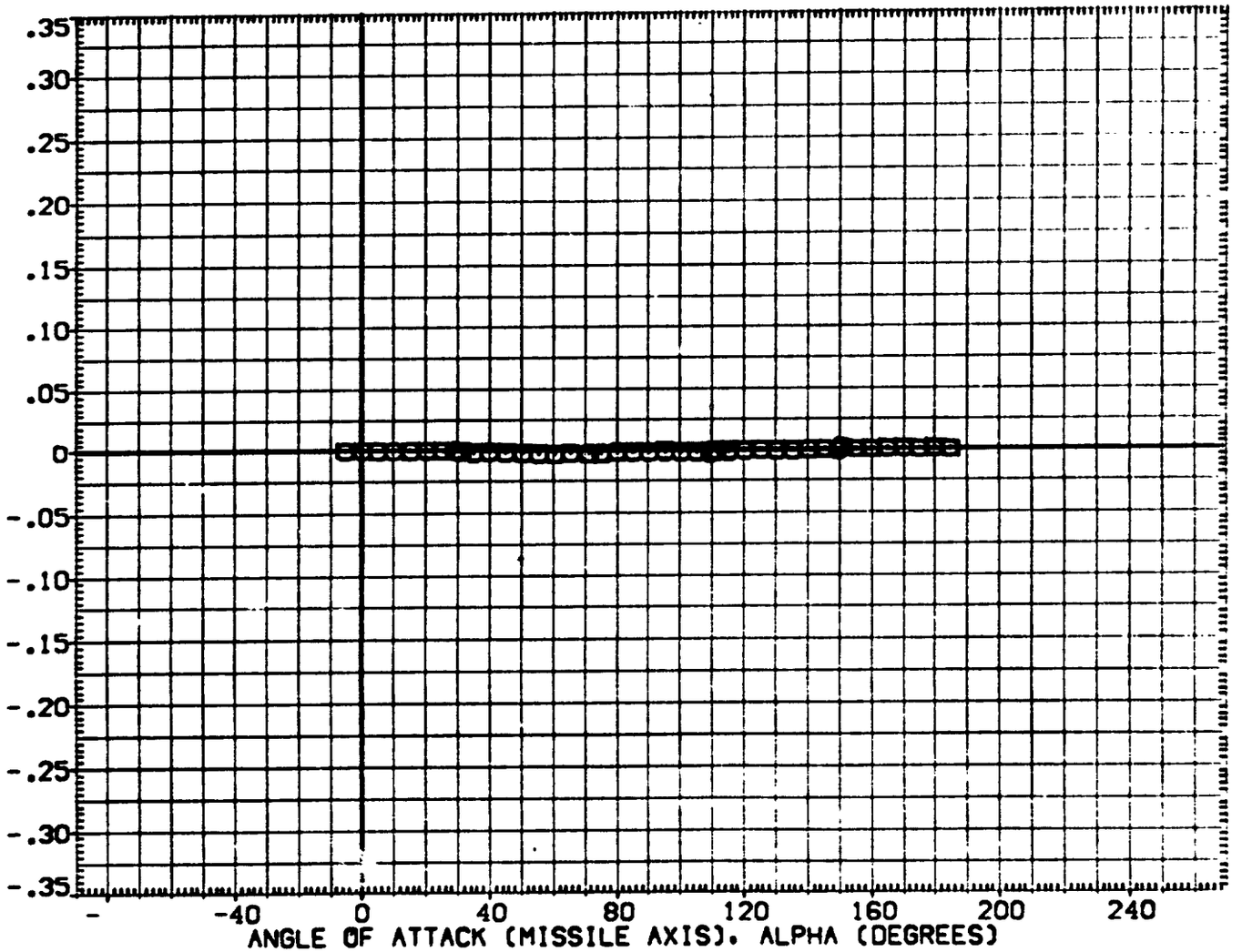

FIG. 10 BASIC TANK VE TANK WITH PROTUBERENCES

(A)PHI = .00

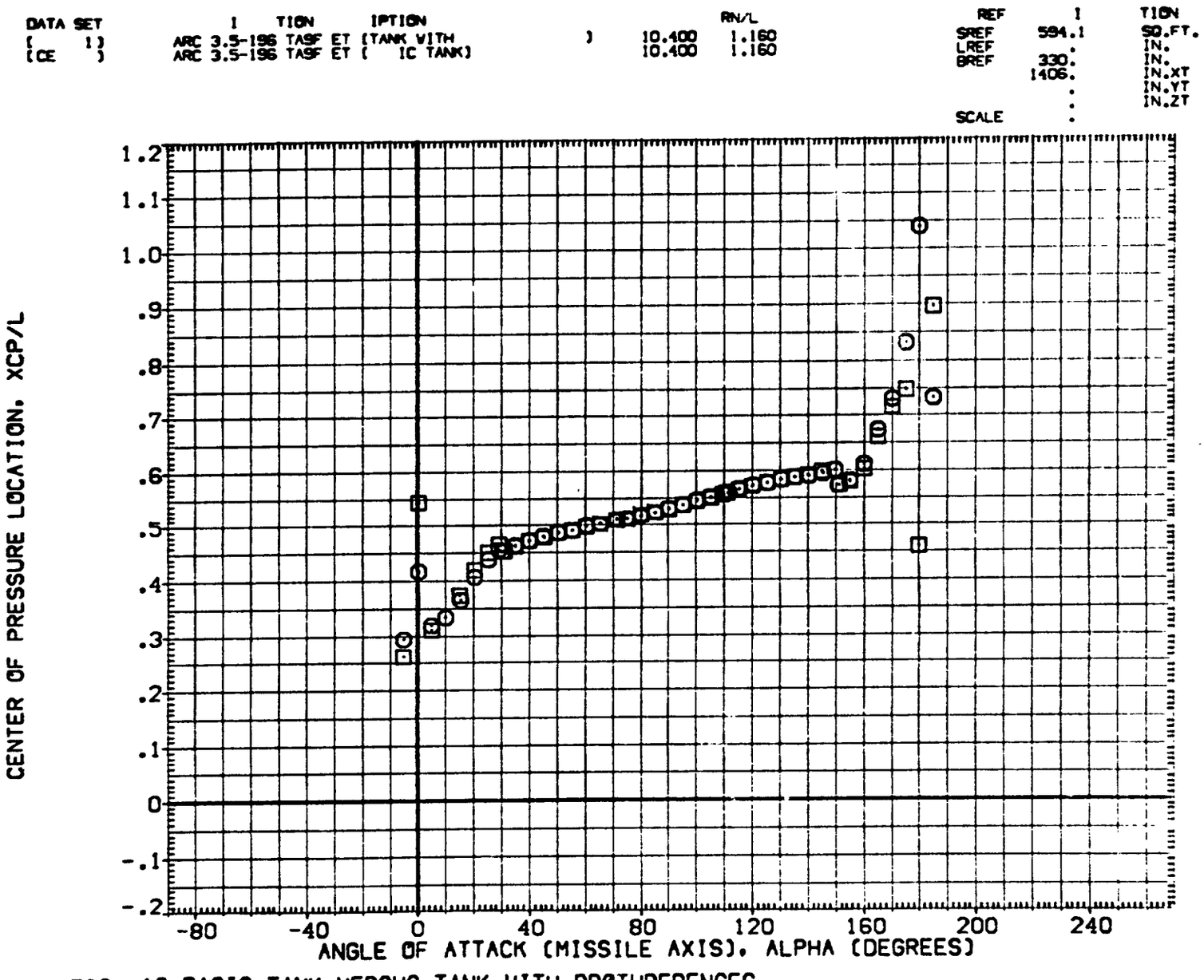

FIG. 10 BASIC TANK VERSUS TANK WITH PROTUBERENCES

(A)PHI = .00

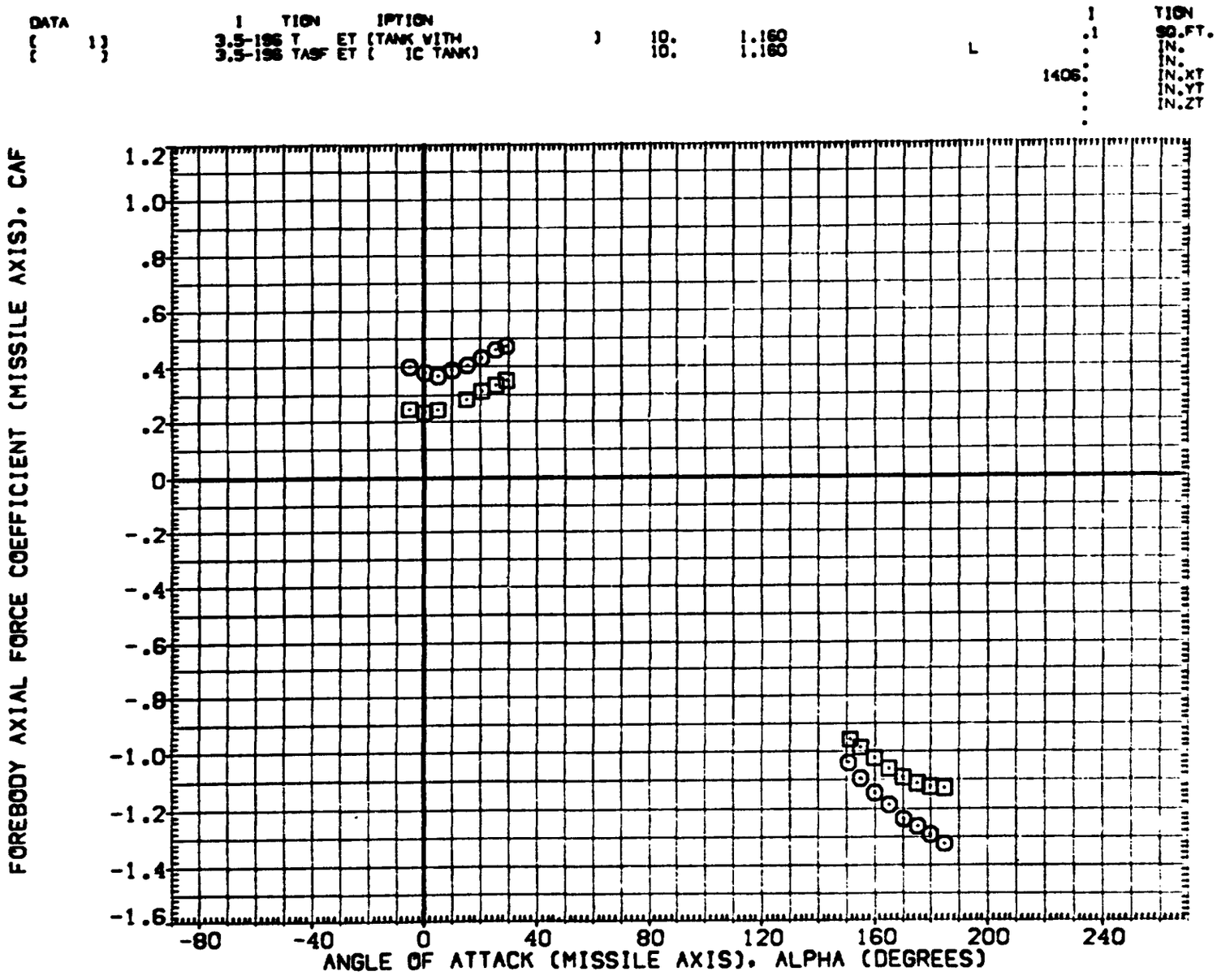

FIG. 10 BASIC TANK VE US TANK WITH PROTUBERENCES

(A)PHI = .00

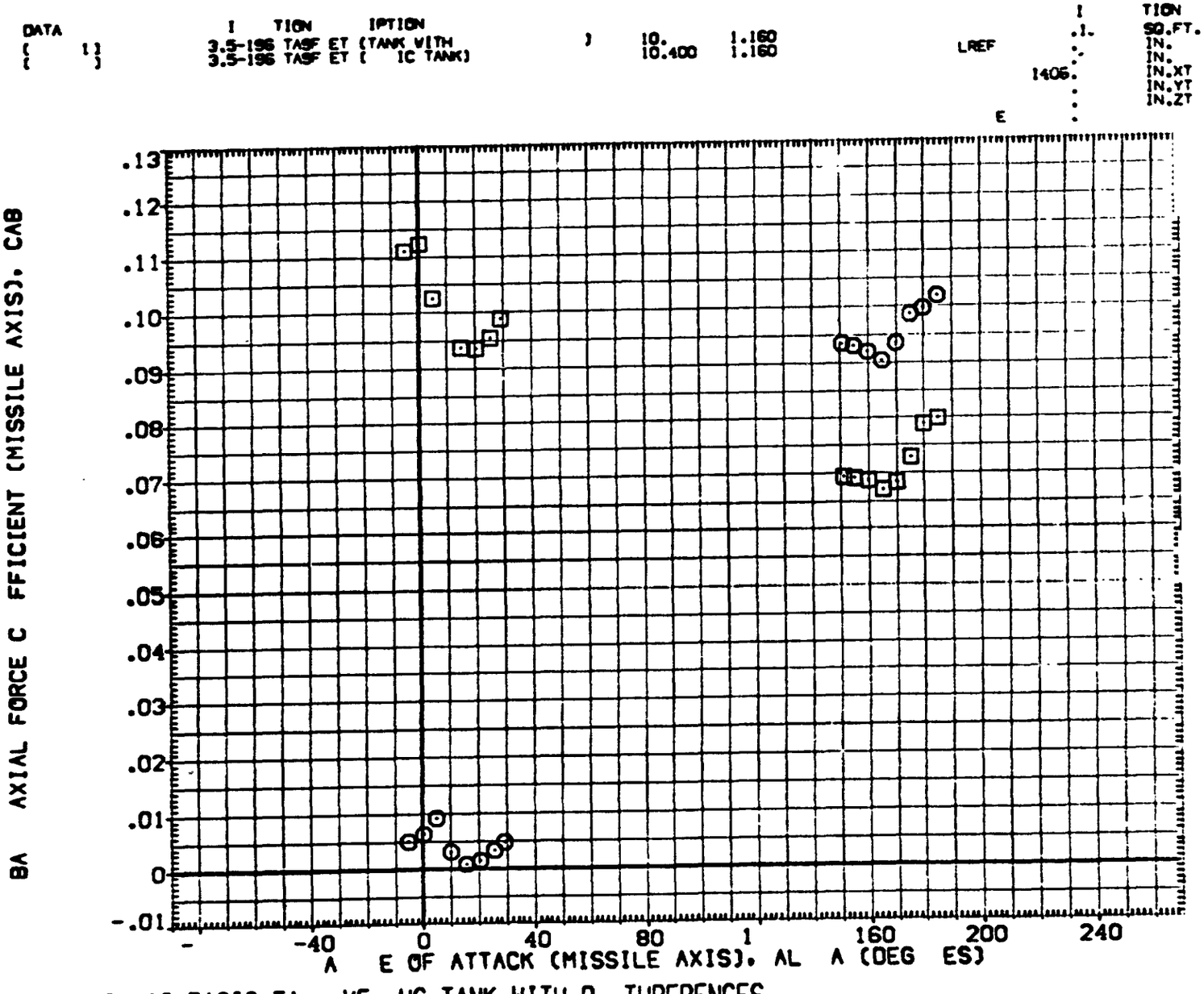

FIG. 10 BASIC TA VE US TANK WITH P TUBERENCES

(A)PHI = .00

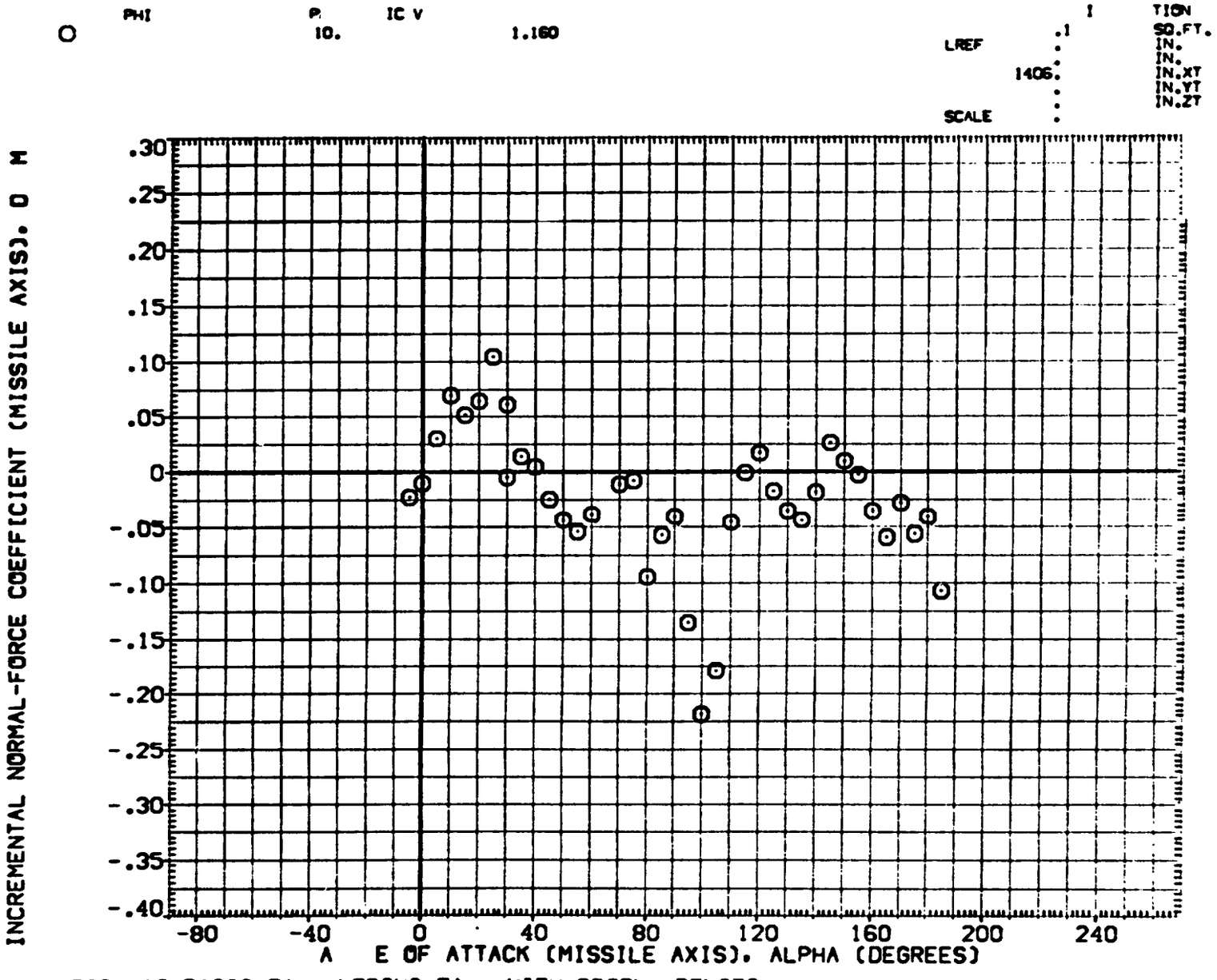

FIG. 10 BASIC TA VERSUS TA WITH PROTU RENCES

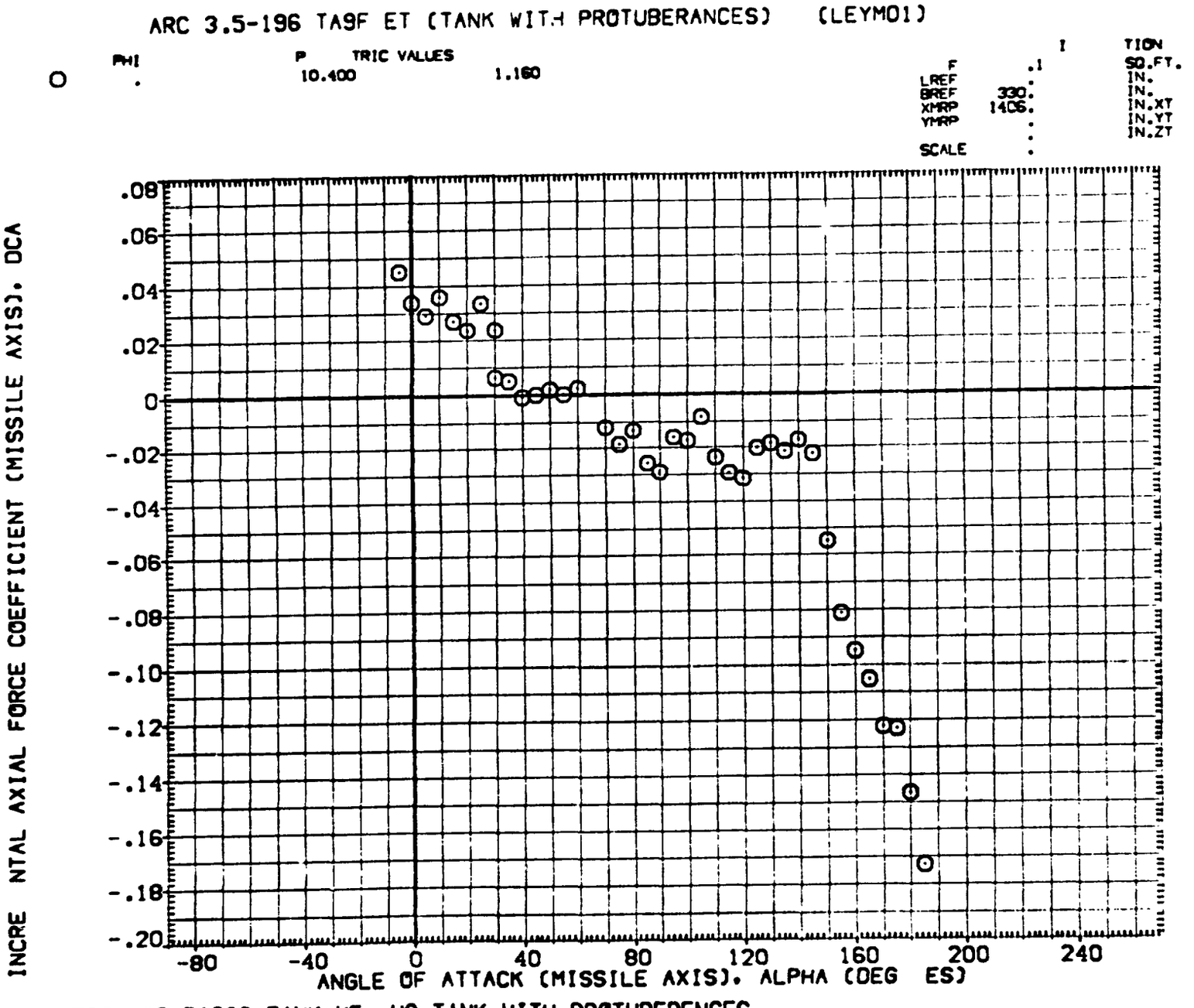

FIG. 10 BASIC TANK VE US TANK WITH PROTUBERENCES

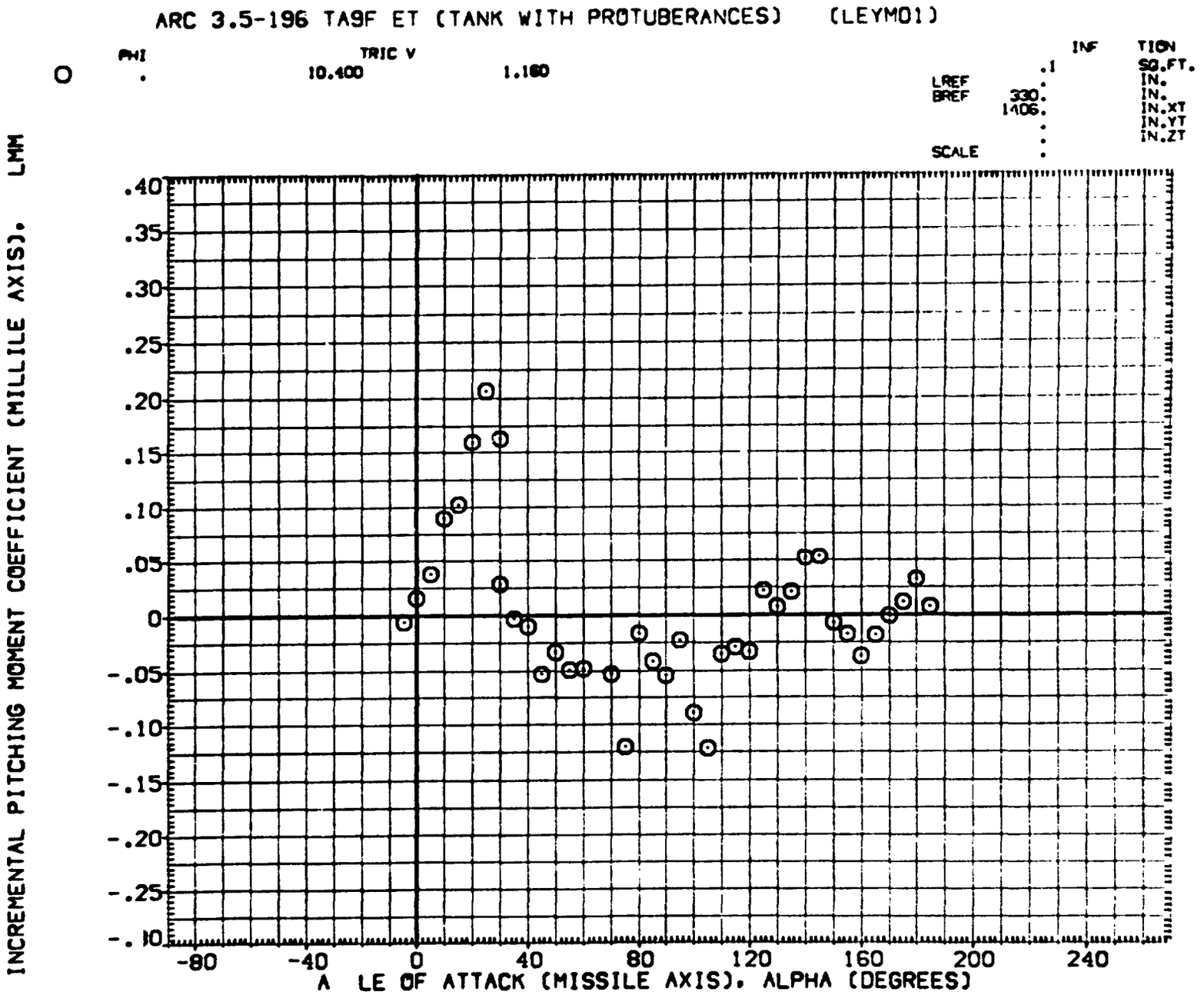

FIG. 10 BASIC TANK VE US TANK WITH PROTUBERENCES

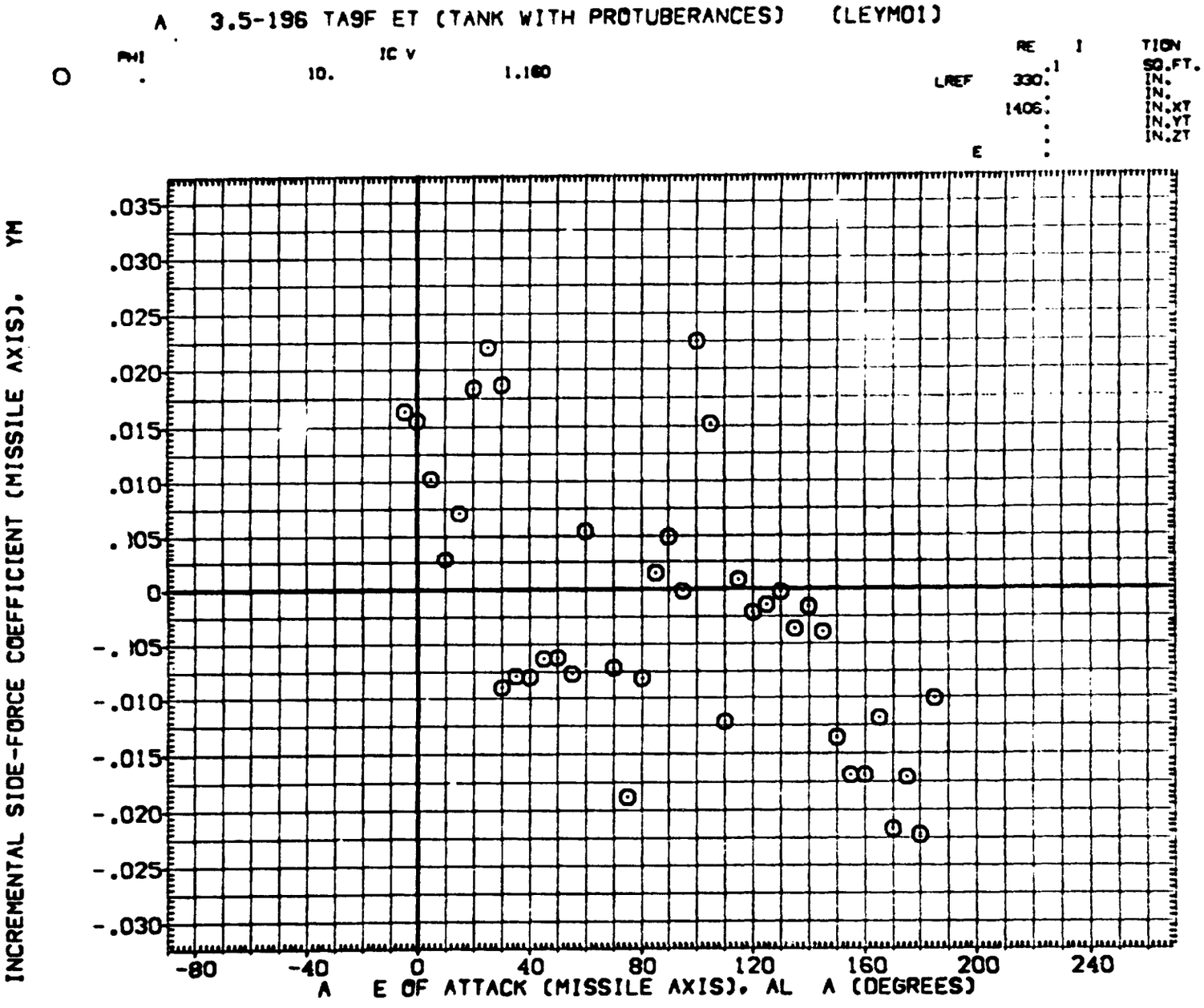

FIG. 10 BASIC TA VE TANK WITH PROTUBE NCES

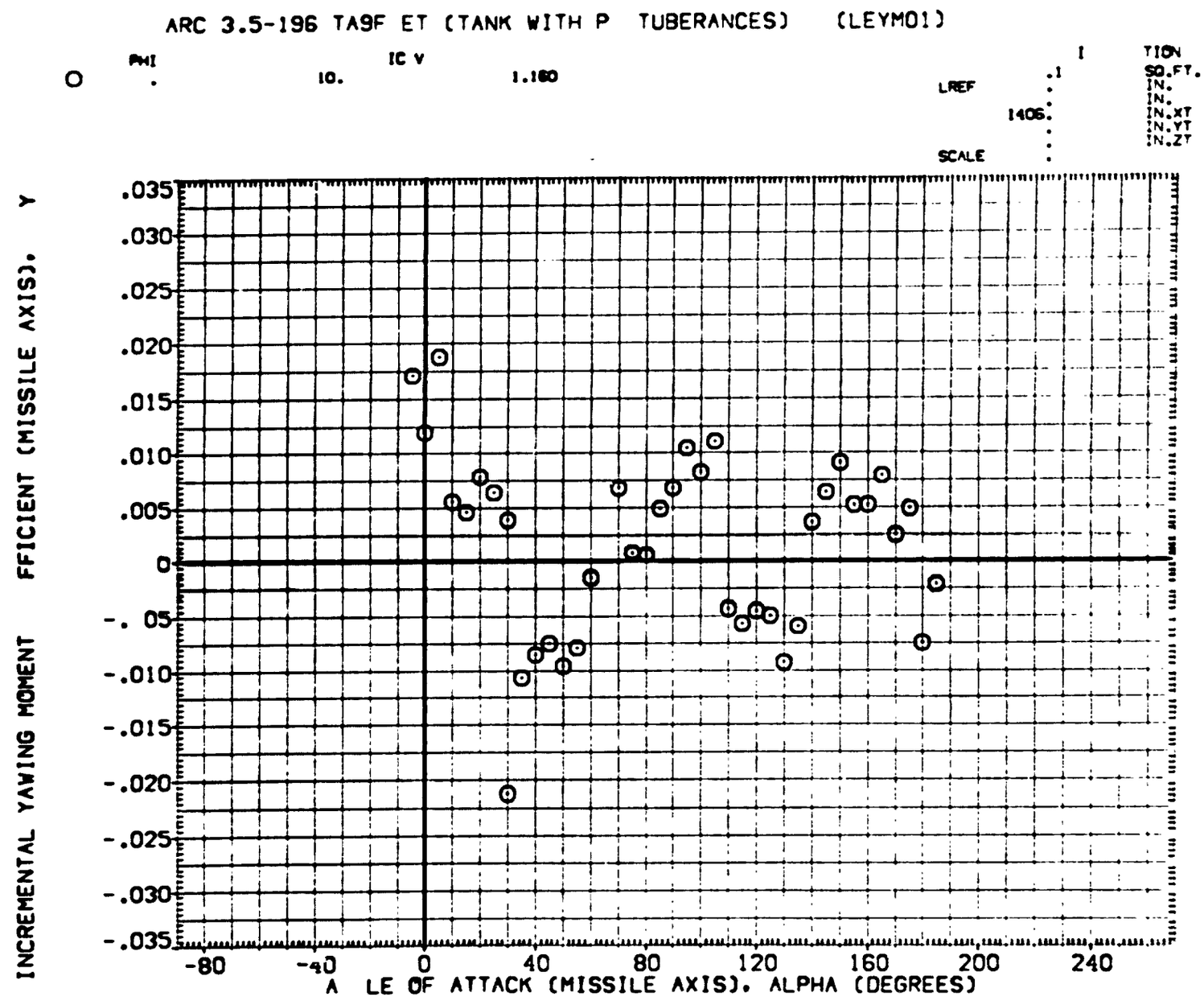

FIG. 10 BASIC TANK VE TANK WITH P TUBE NCES

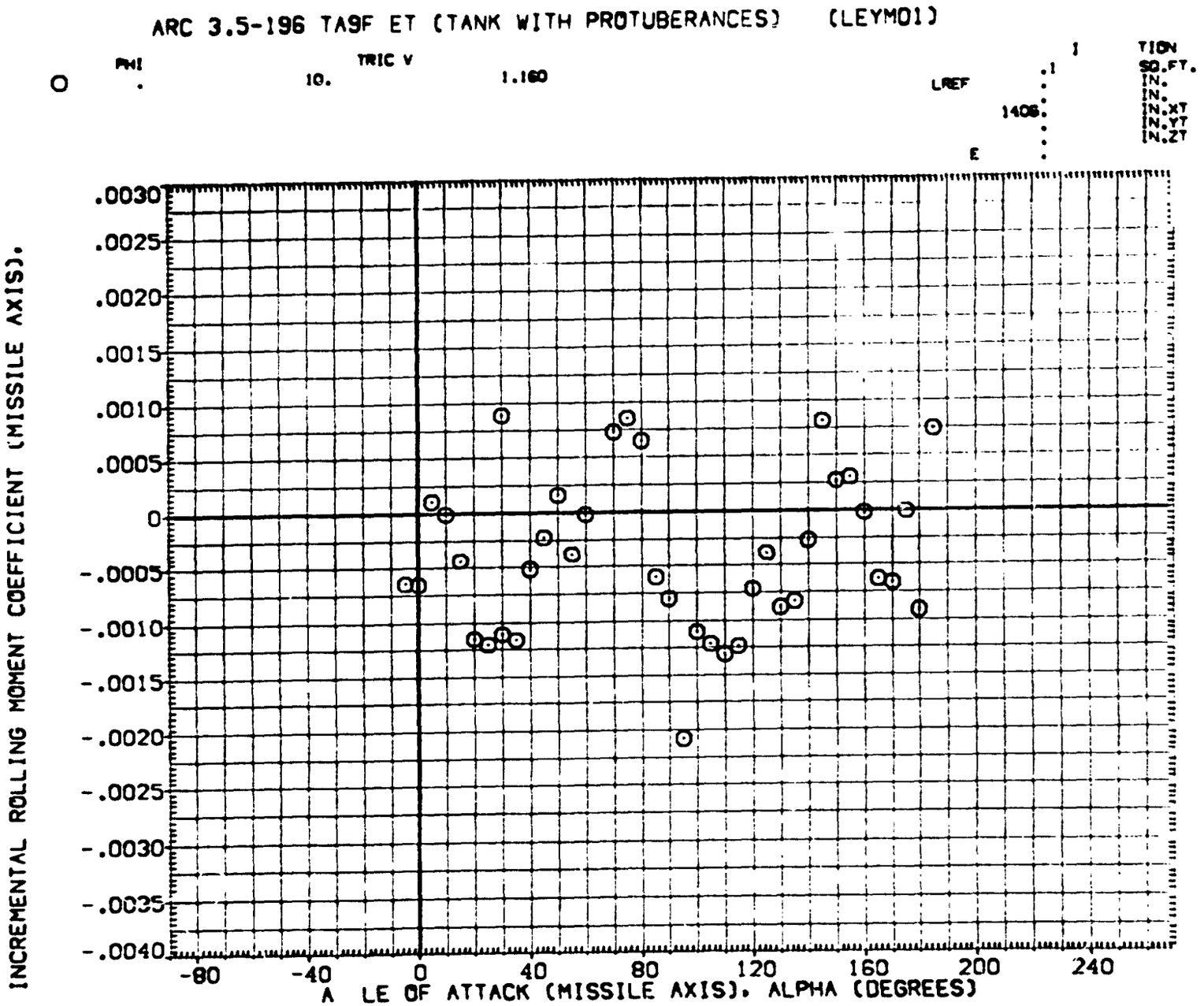

FIG. 10 BASIC TANK VERSUS TANK WITH P TUBERENCES

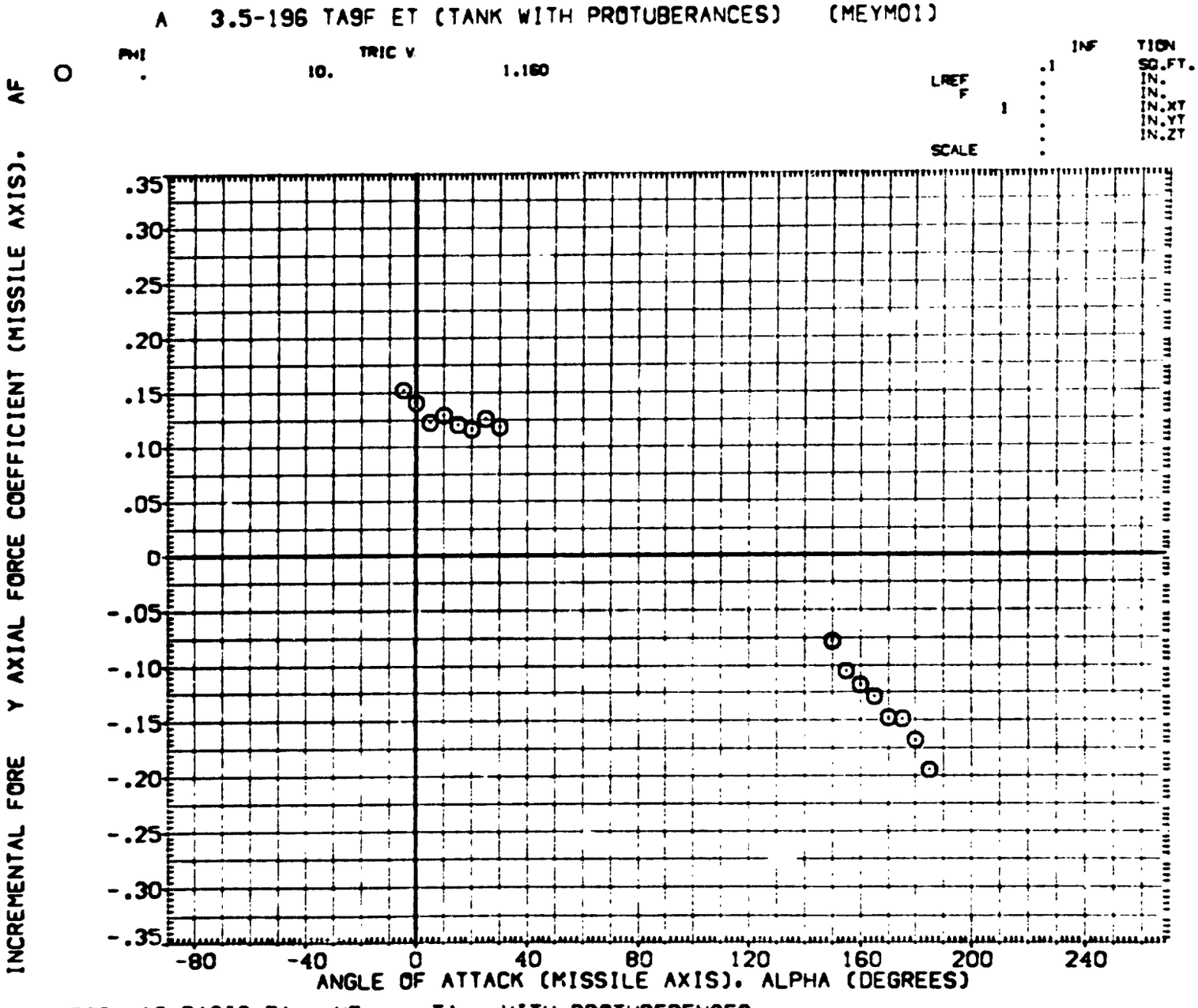

FIG. 10 BASIC TA VE. TA WITH PROTUBERENCES

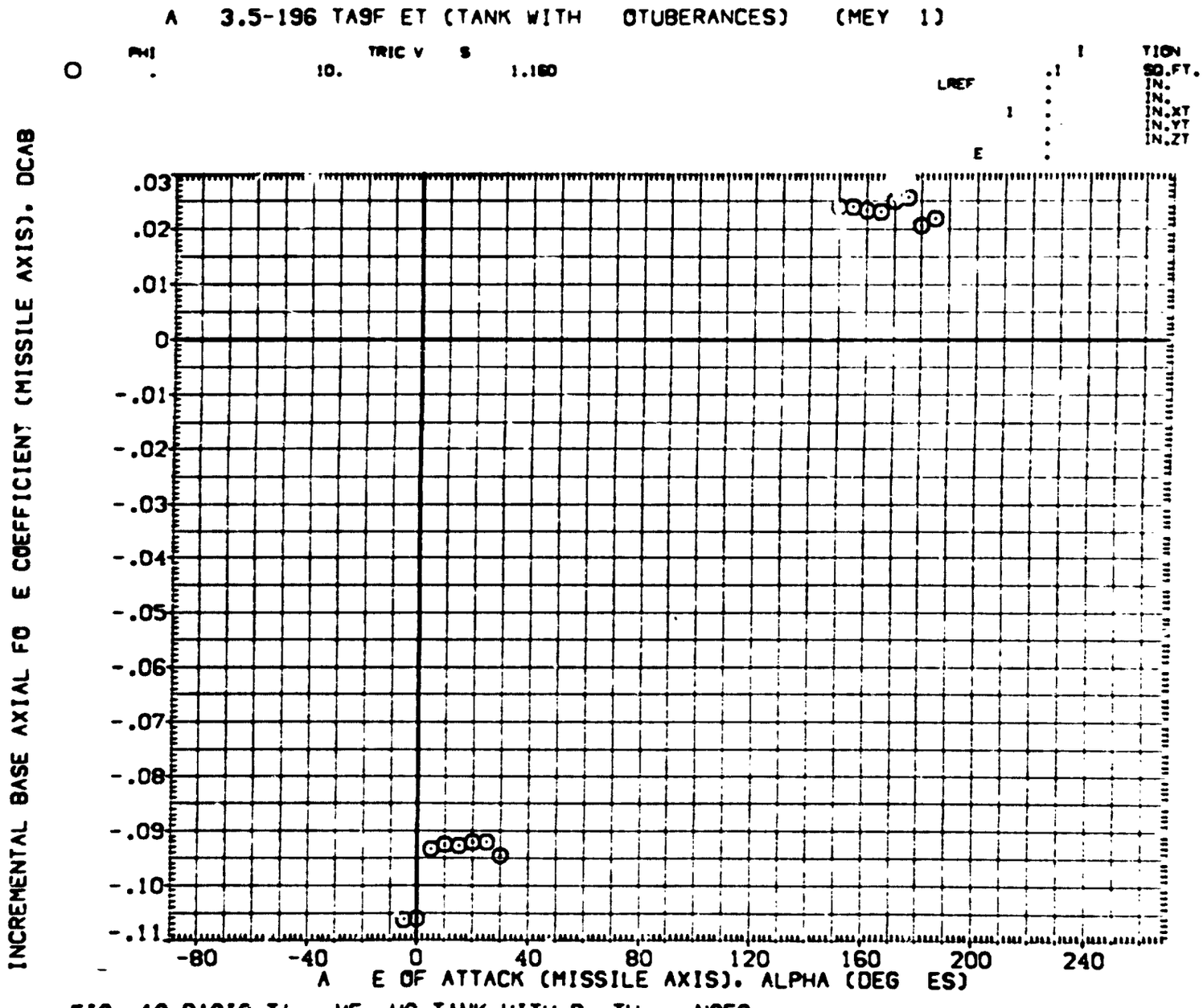

FIG. 10 BASIC T/ VE US TANK WITH P. TU NCES

DATA SET		CONFIGURATION DESCRIPTION			MACH	RN/L
(CE)	○	ARC 3.5-196 TASF ET (BASIC TANK)			10.400	1.160
(WEYMO1)	□	ARC 3.5-196 TASF ET (TANK WITH	UBE	ES)	10.400	1.160

REFERENCE INF		TION
SREF	594.1360	SQ.FT.
LREF	330.2000	IN.
BREF	330.2000	IN.
XMRP	1406.	IN.XT
YMRP	.	IN.YT
SCALE	.	IN.ZT

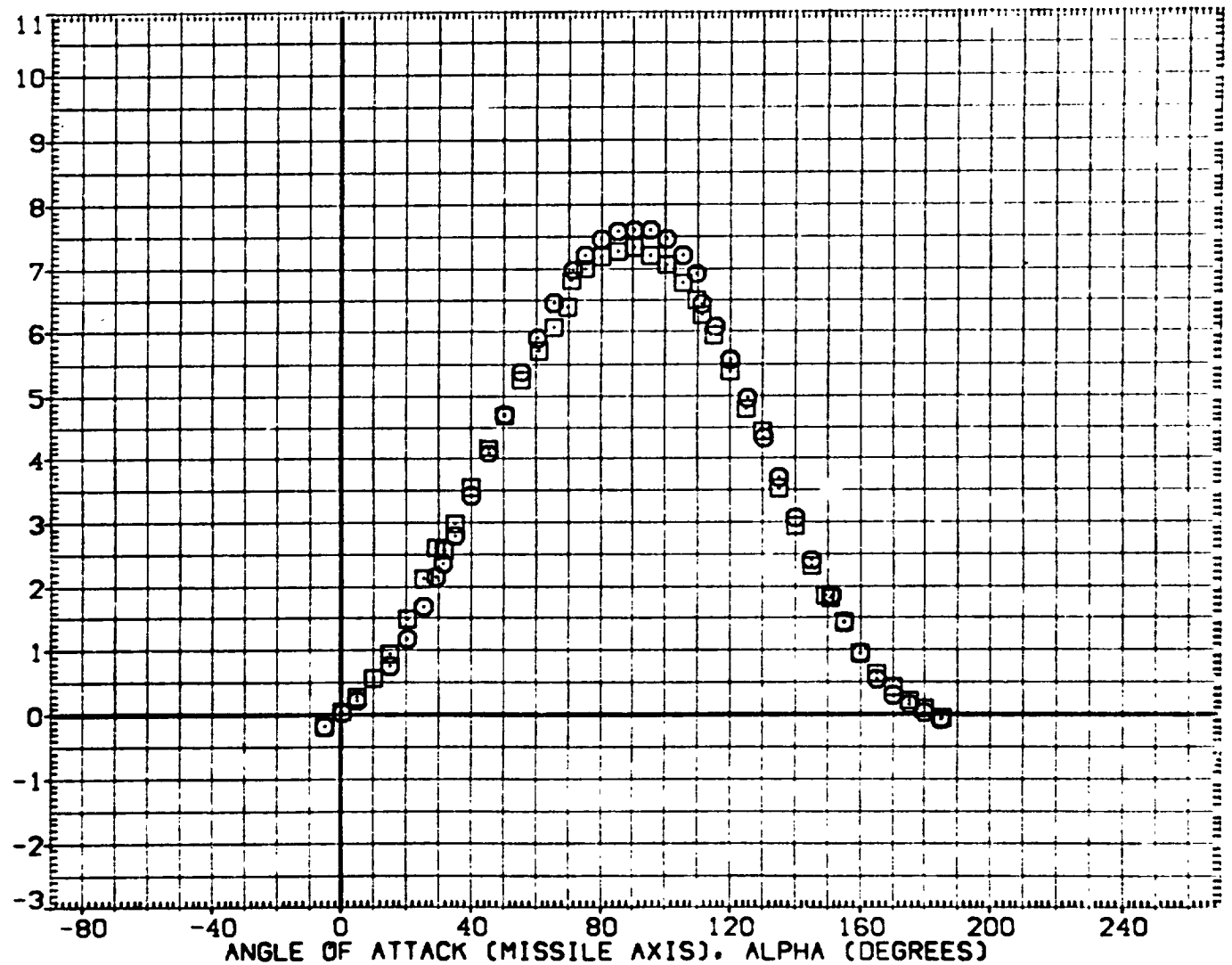

FIG. 10 BASIC TANK VERSUS TANK WITH PROTUBERENCES

(A)PHI = .00 (B)180.00

DATA SET		I TION DE IPTION		RN/L	
(DE)	8	ARC 3.5-196 TA9F ET (BASIC TANK)		10.400	1.160
(VEYMOI)	8	ARC 3.5-196 TA9F ET (TANK WITH PRO	S)	10.400	1.160

REFERENCE INF		TION
SREF	594.1	SQ.FT.
LREF	330.	IN.
BREF	330.	IN.
XMRP	1406.	IN.XT
YMRP	.	IN.YT
SCALE	.	IN.ZT

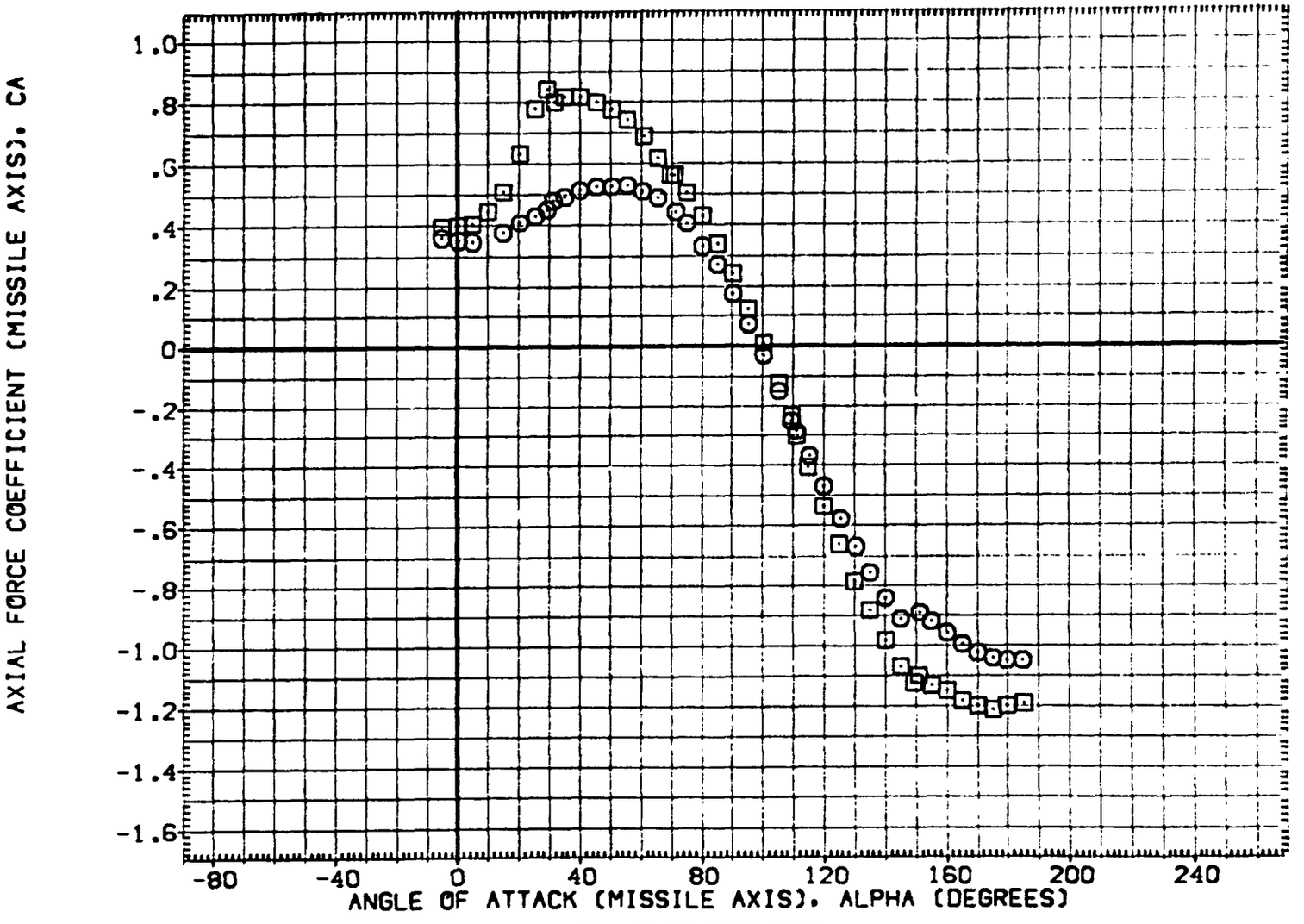

FIG. 10 BASIC TANK VERSUS TANK WITH PROTUBERENCES

(A)PHI = .00 (B)180.00

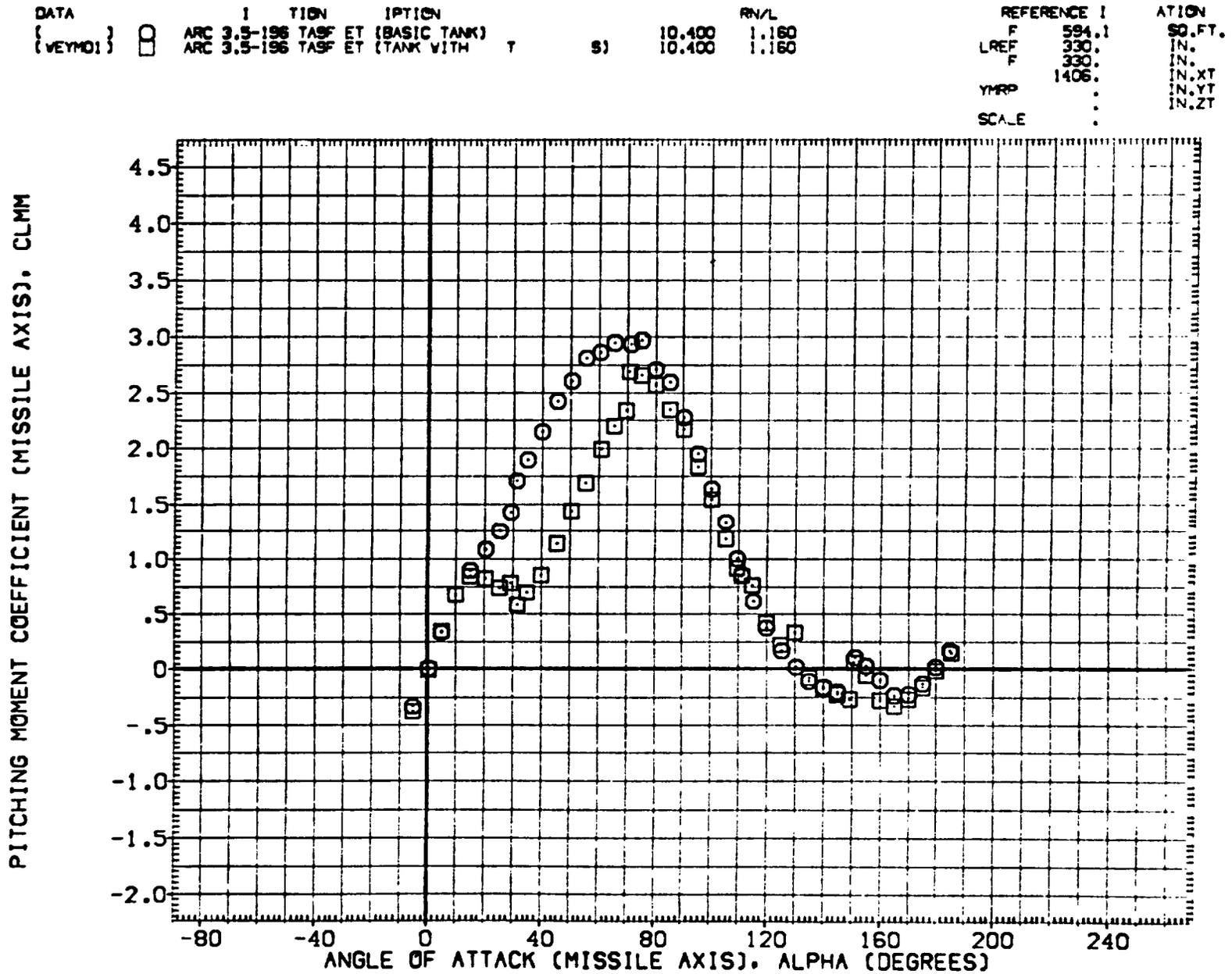

FIG. 10 BASIC TANK VERSUS TANK WITH PROTUBERENCES

(A)PHI = .00 (B)180.00

DATA SET		I TION DE IPTION	MACH	RN/L
(CE)	☐	ARC 3.5-196 TASF ET (BASIC TANK)	10.400	1.160
(VEYMOI)	☐	ARC 3.5-196 TASF ET (TANK WITH UBER S)	10.400	1.160

REFERENCE INF		TION
SREF	594.1360	SQ.FT.
LREF	330.	IN.
BREF	330.	IN.
XMRP	1406.	IN.XT
YMRP	.	IN.YT
ZMRP	.	IN.ZT
SCALE	.	

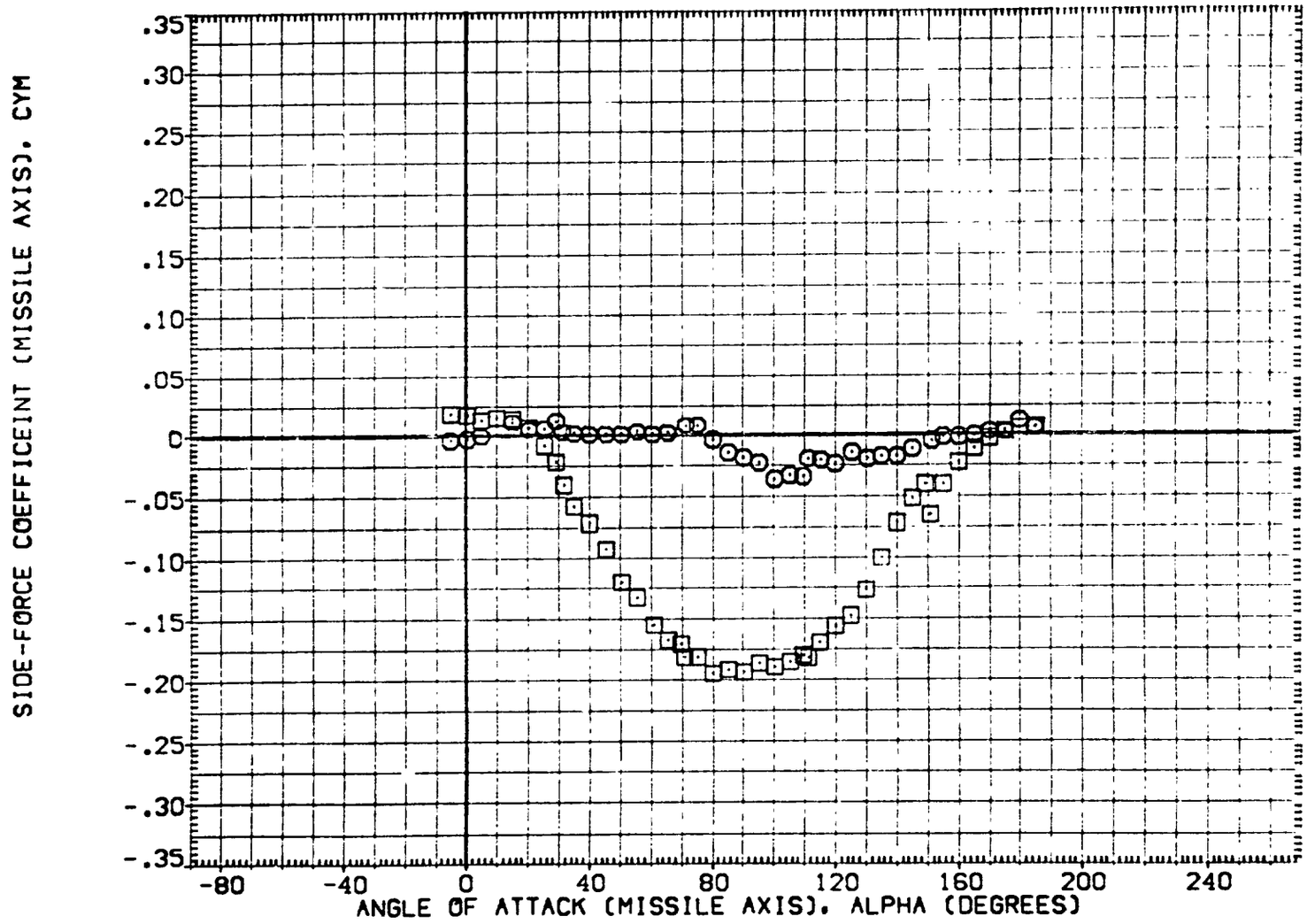

FIG. 10 BASIC TANK VERSUS TANK WITH PROTUBERENCES

(A)PHI = .00 (B)180.00

DATA SET		MACH	RN/L	REFE	INF	TION
(CE)	3.5-196 TASF ET (IC TANK)	10.400	1.160	F	594.1	SQ.FT.
(1)	ARC 3.5-196 TASF ET (TANK WITH S)	10.400	1.160	LREF	330.	IN.
					330.	IN.
					1406.	IN.XT
					:	IN.YT
					:	IN.ZT
				SCALE	:	

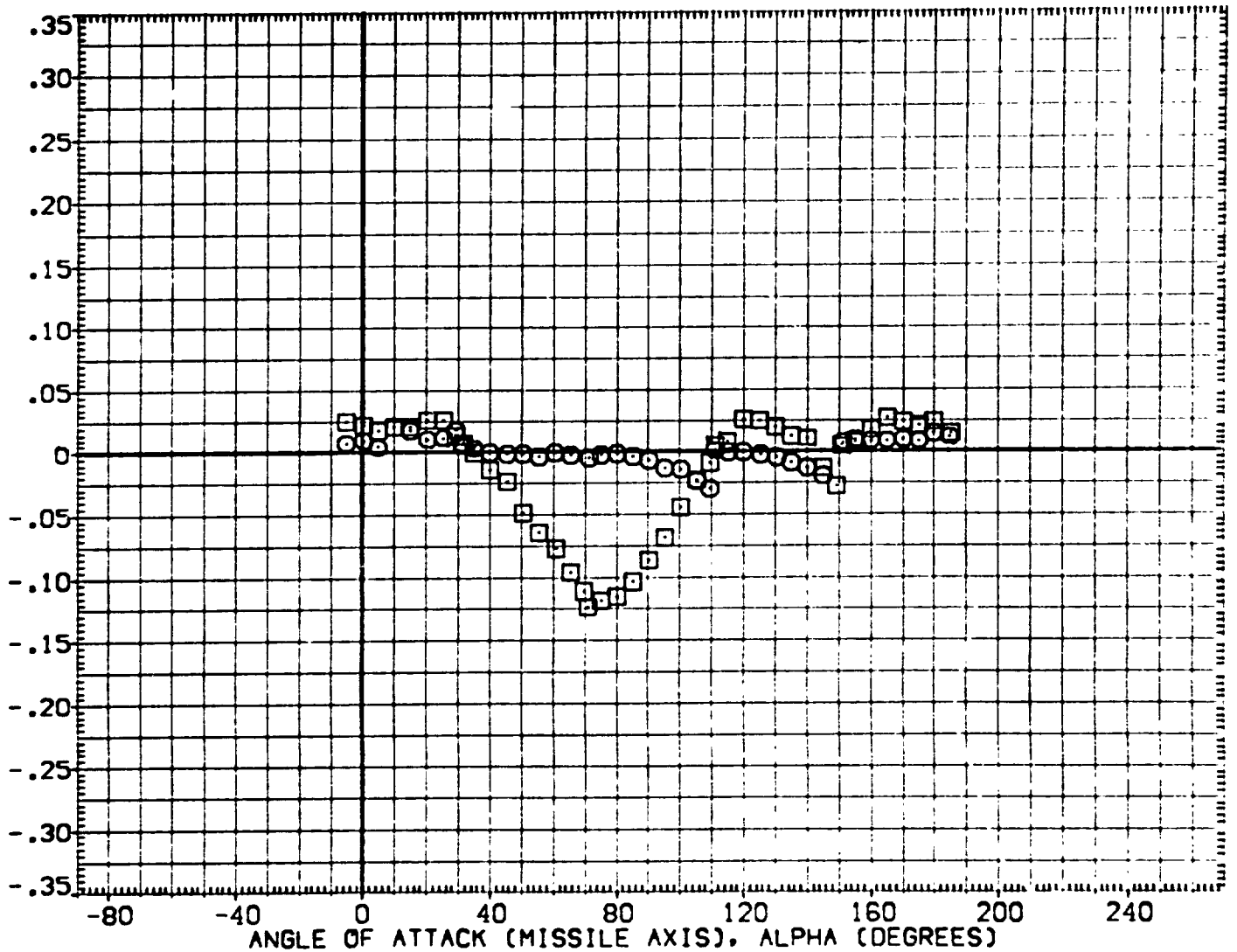

FIG. 10 BASIC TANK VERSUS TANK WITH PROTUBERENCES

(A)PHI = .00 (B)180.00

DATA SET		I TION DE IPTION	MACH	RN/L
[CE]	□	ARC 3.5-196 TASF ET [BASIC TANK)	10.400	1.160
[VEYMOI]	□	ARC 3.5-196 TASF ET [TANK WITH PROTUBER S)	10.400	1.160

REFE	I	TION
SREF	594.1	SQ.FT.
LREF	330.	IN.
BREF	330.	IN.
	1406.	IN.XT
YMRP	.	IN.YT
ZMRP	.	IN.ZT
SCALE	.	

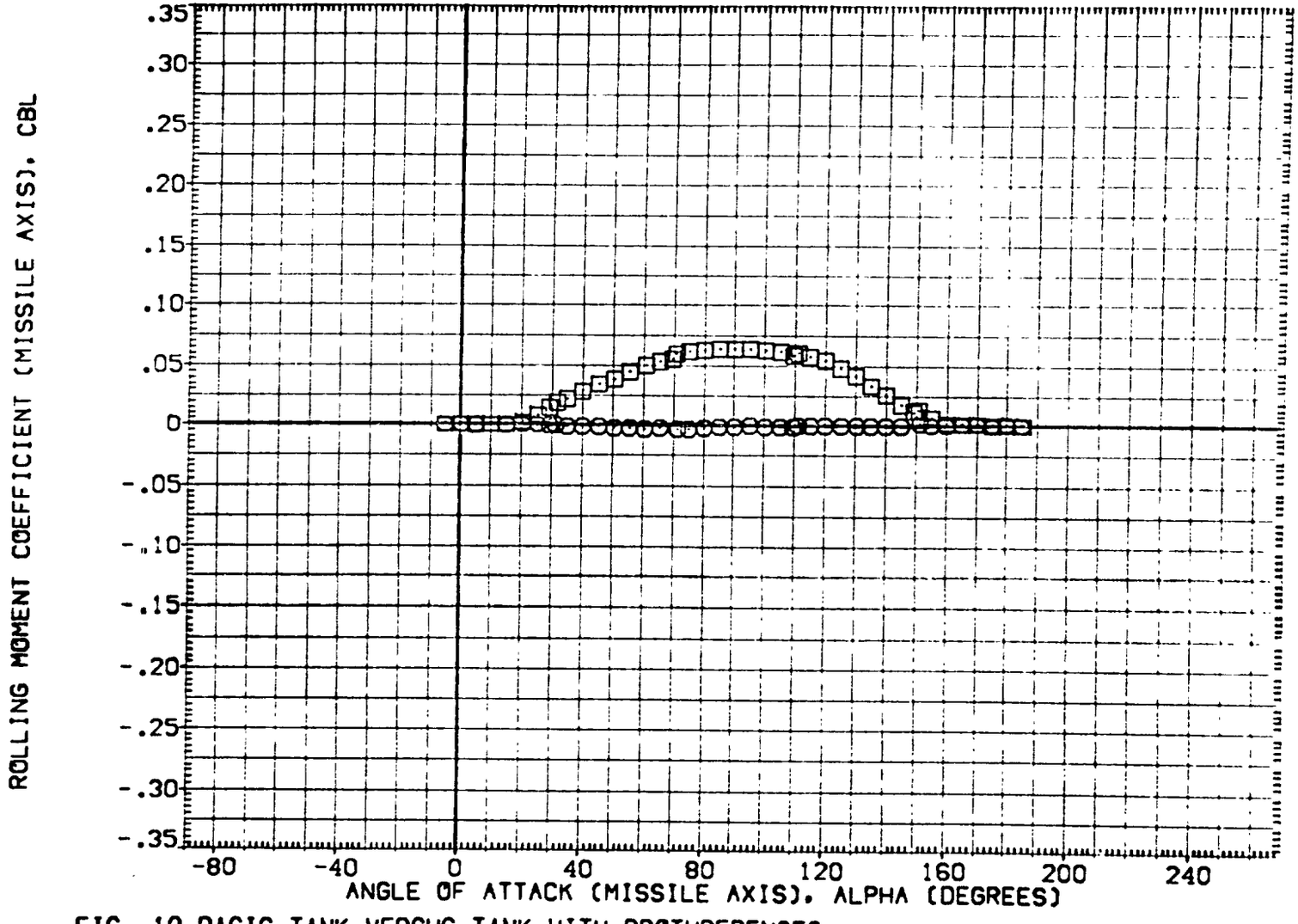

FIG. 10 BASIC TANK VERSUS TANK WITH PROTUBERENCES

(A)PHI = .00 (B)180.00

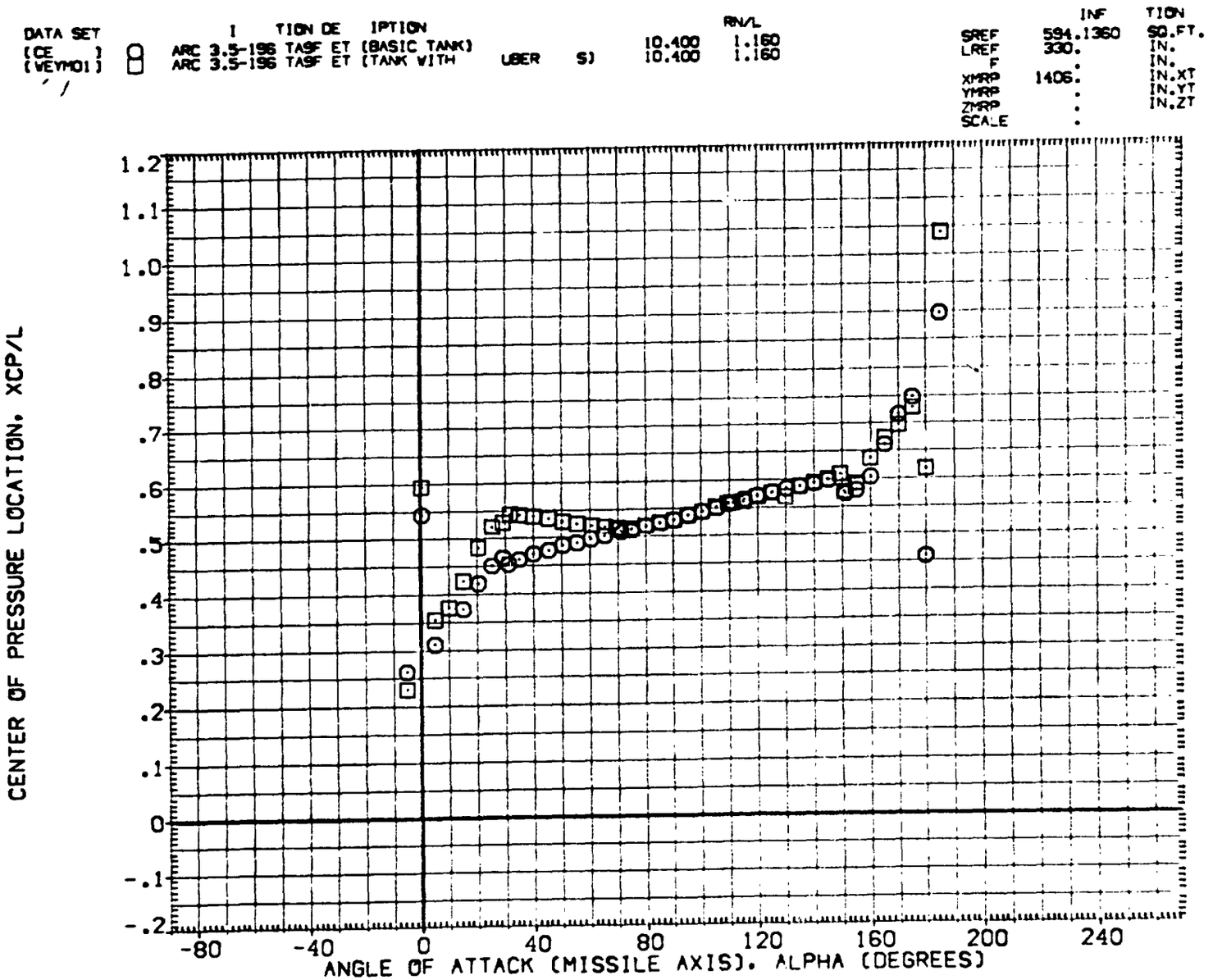

FIG. 10 BASIC TANK VERSUS TANK WITH PROTUBERENCES

(A)PHI = .00 (B)180.00

DATA SET		CONFIGURATION DESCRIPTION	MACH	RN/L
(UEYM01)	○	ARC 3.5-196 TASF ET (TANK WITH S)	10.400	1.160
( )	□	ARC 3.5-196 TASF ET (TANK WITH PROTUBERANCES)	10.400	.390
(CE)	◇	ARC 3.5-196 TASF ET (TANK WITH PROTUBERANCES)	10.400	1.740

REFE	INF	TION
SREF	594.1	SQ.FT.
LREF	330.	IN.
BREF	330.	IN.
XMRP	1406.	IN.XT
YMRP	.	IN.YT
ZMRP	.	IN.ZT
SCALE	.	

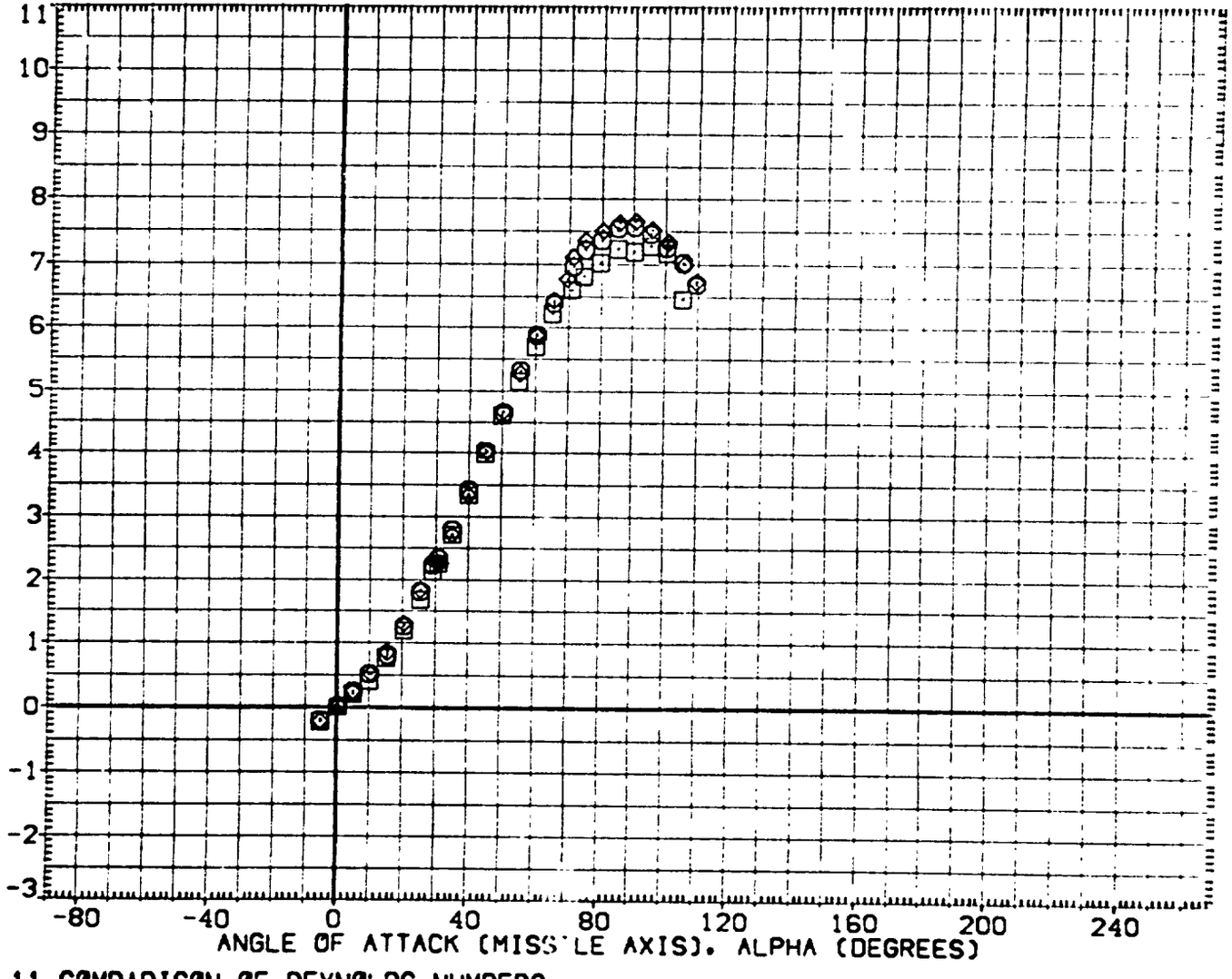

FIG. 11 COMPARISON OF REYNOLDS NUMBERS

(A)PHI = .00

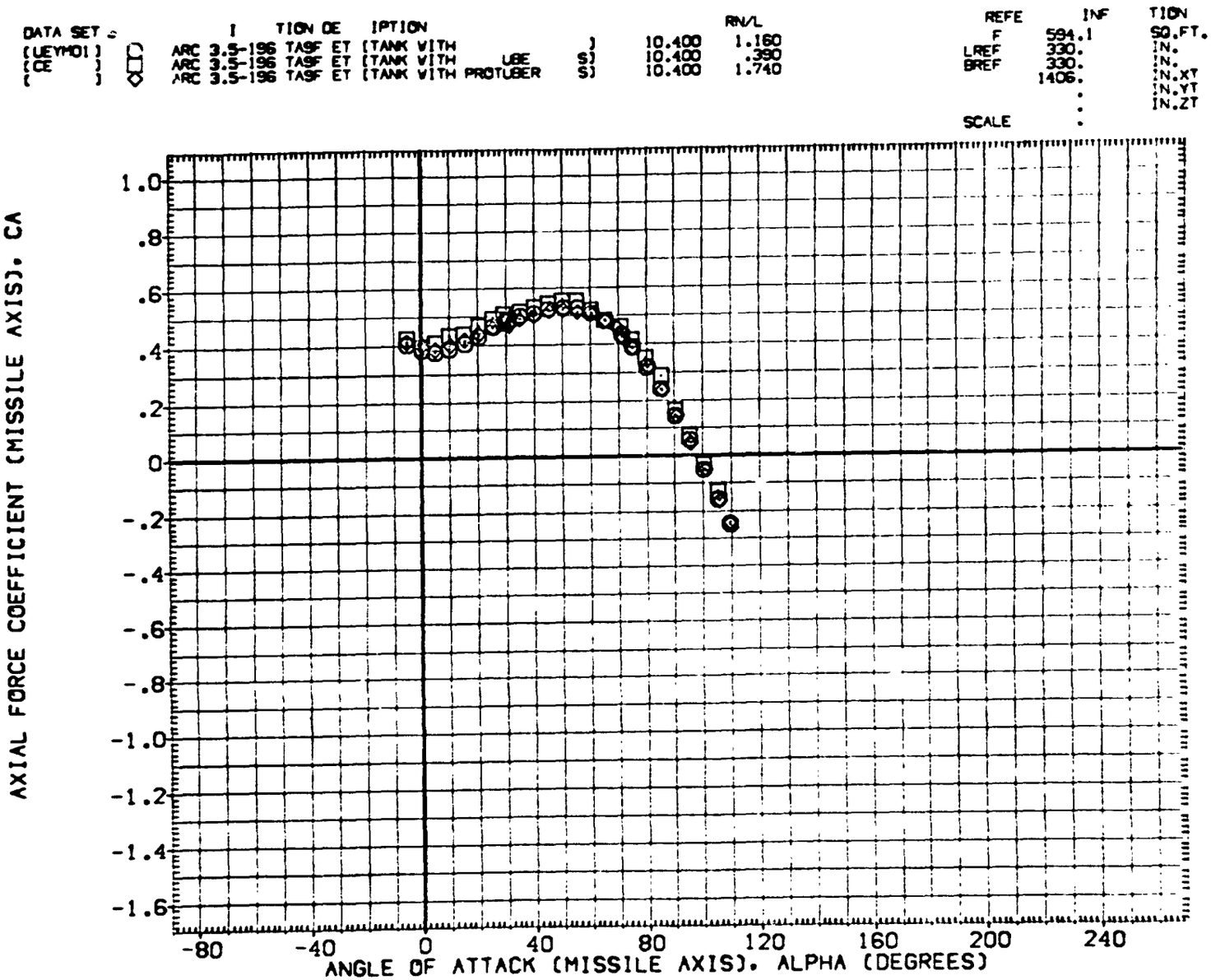

FIG. 11 COMPARISON OF REYNOLDS NUMBERS

(A)PHI = .00

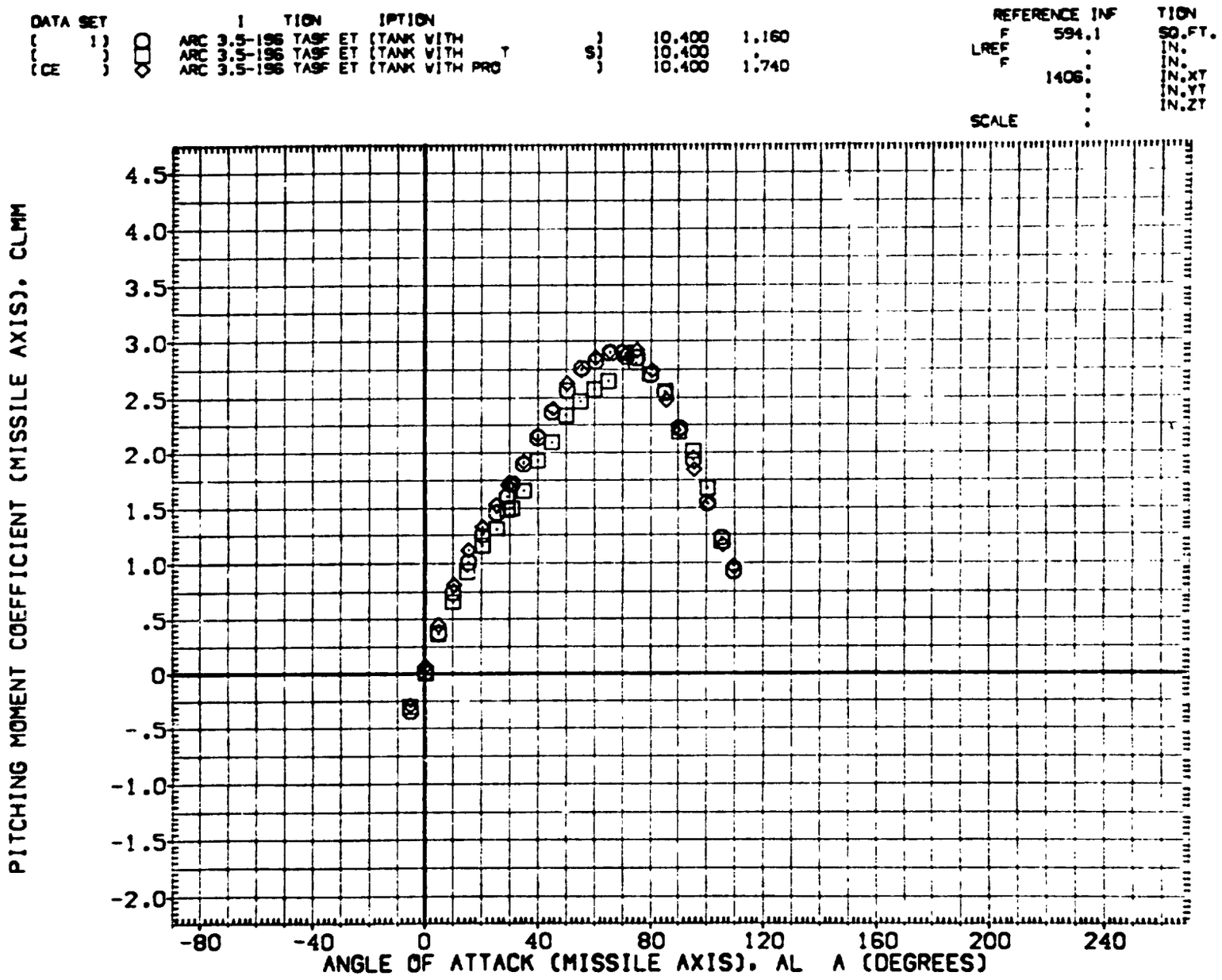

FIG. 11 CO ARI N OF REY L E

(A)PHI = .00

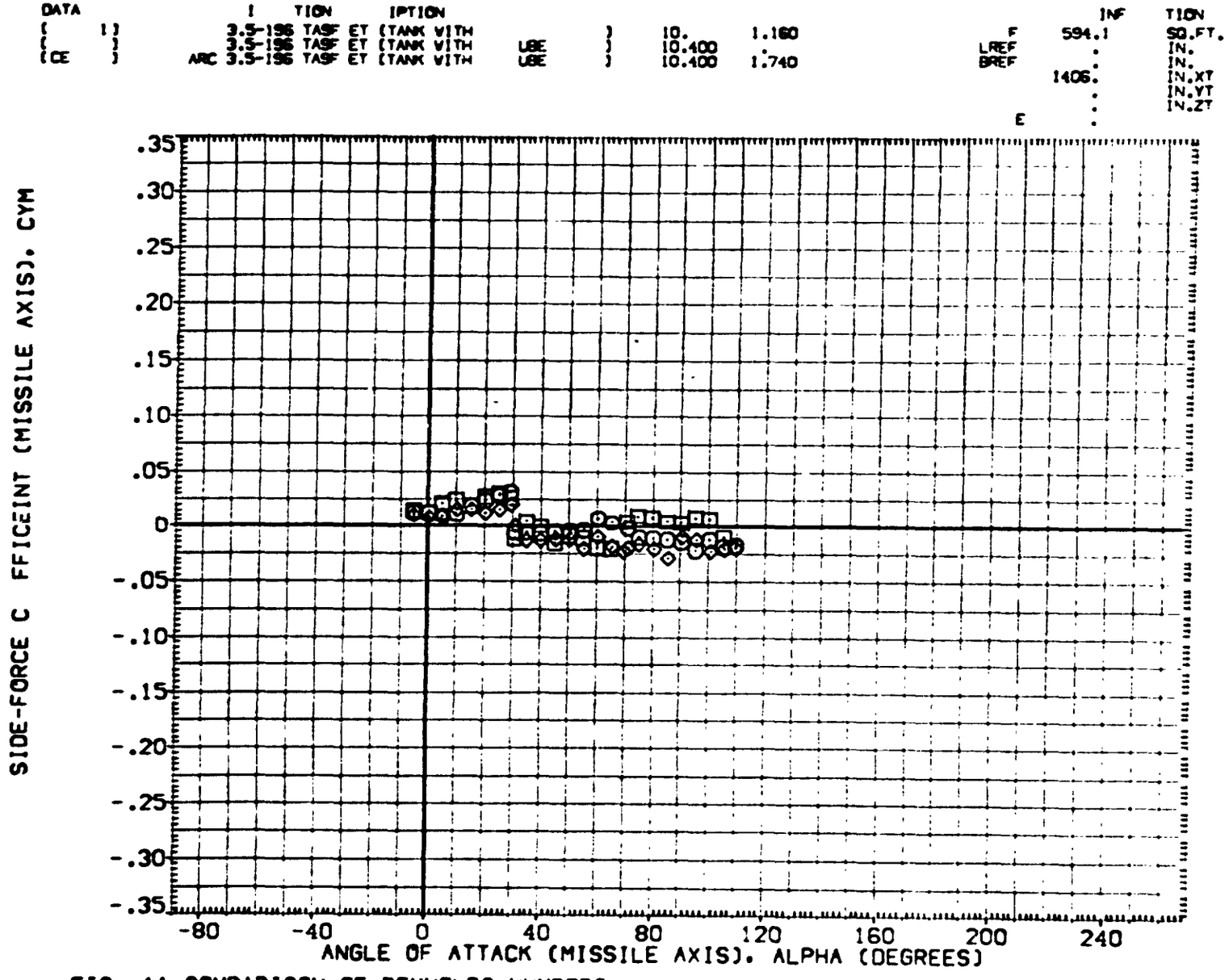

FIG. 11 COMPARISON OF REYNOLDS NUMBERS

(A)PHI = .00

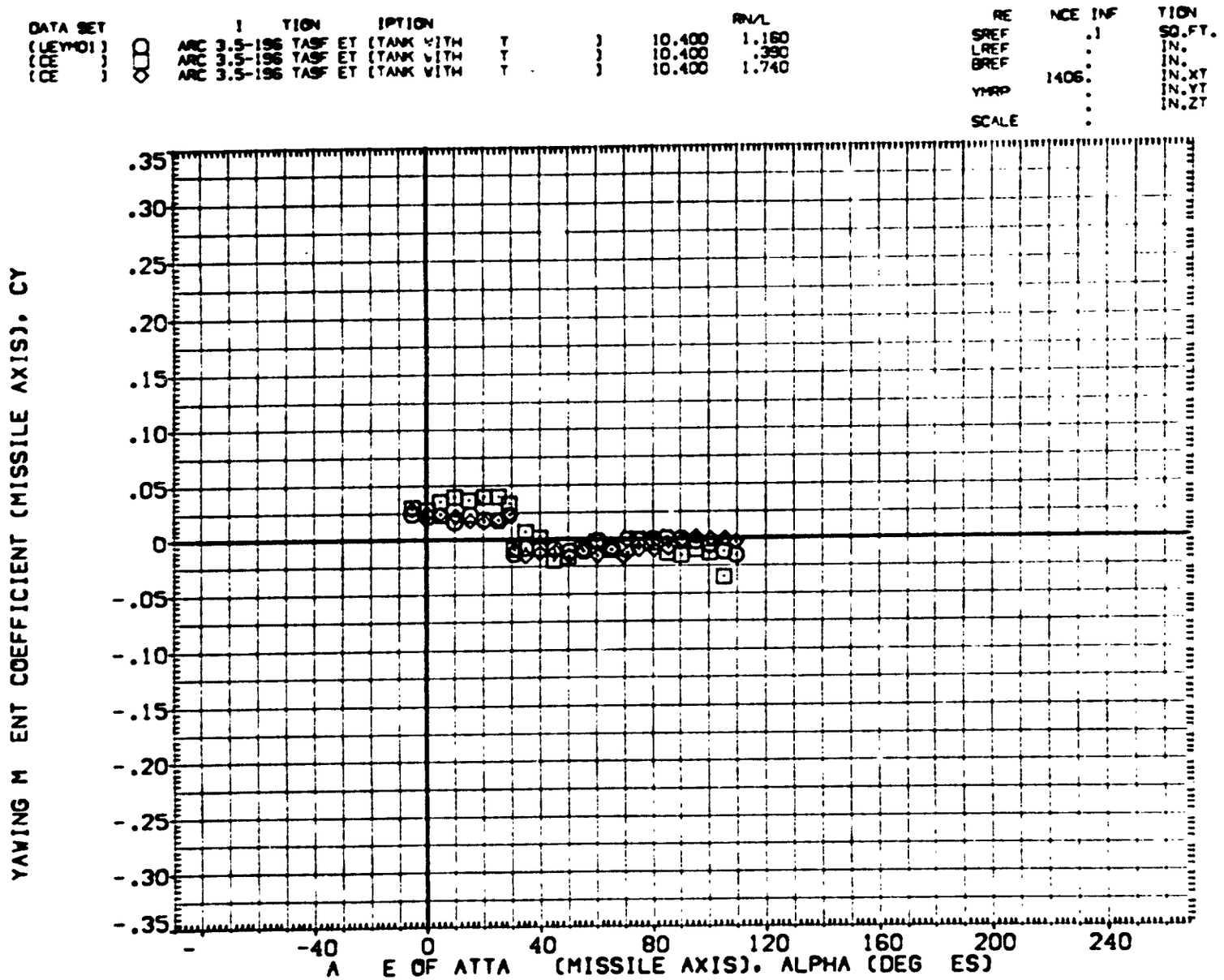

FIG. 11 C ARIS OF Y LDS NUMBERS

(A)PHI = .00

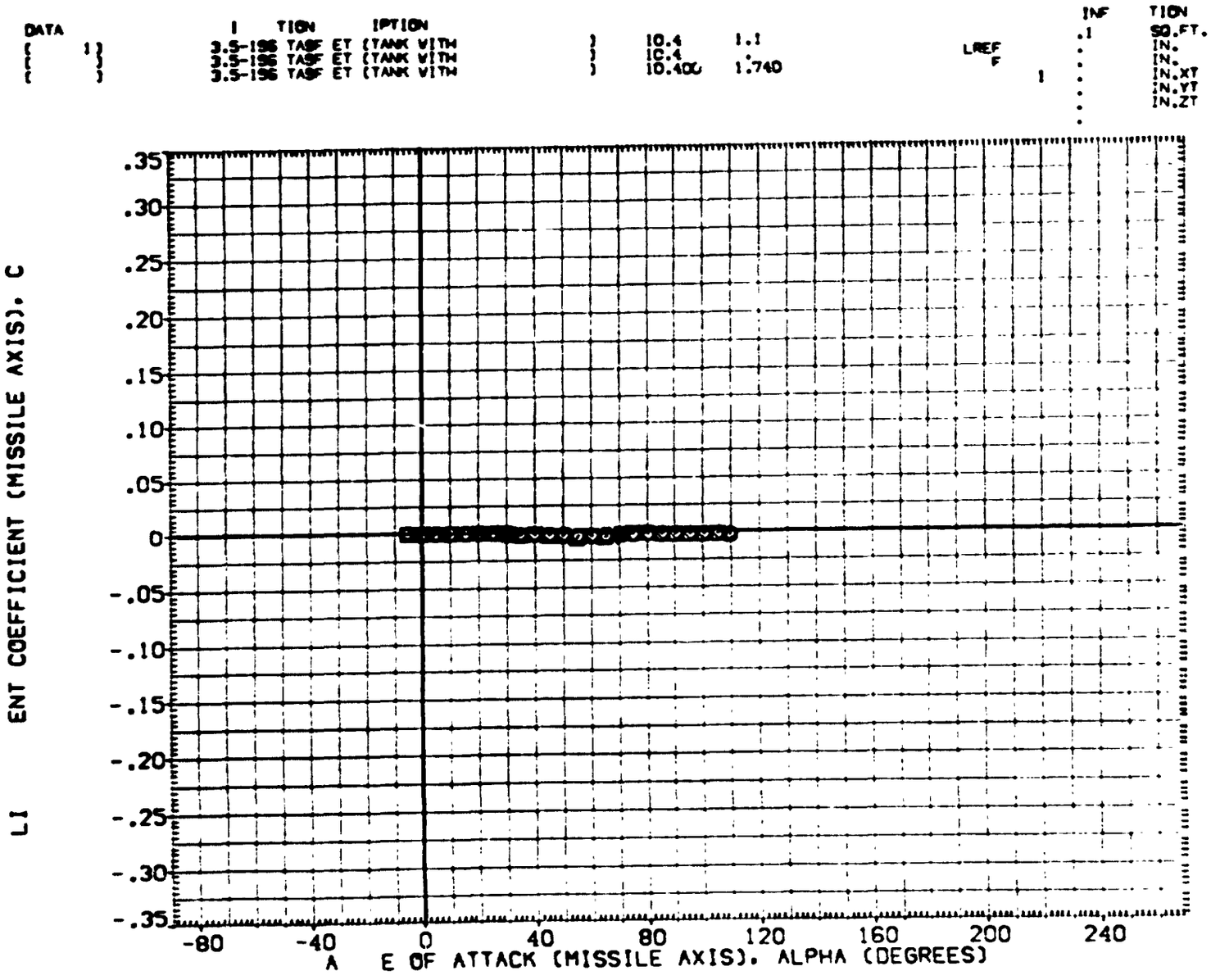

FIG. 11 COMPARISON OF REYNOLDS NUMBERS

(A)PHI = .00

DATA SET				RN/L	
(1)	3.5-196 TASF ET (TANK WITH		)	10.400	1.160
(CEYHOS)	3.5-196 TASF ET (TANK WITH		)	10.400	.390
(CEYHOS)	ARC 3.5-196 TASF ET (TANK WITH	T	)	10.400	1.740

REFERENCE I		TION
SREF	.1	SQ.FT.
LREF	.	IN.
BREF	330.	IN.
	1406.	IN.XT
	.	IN.YT
	.	IN.ZT
E	.	

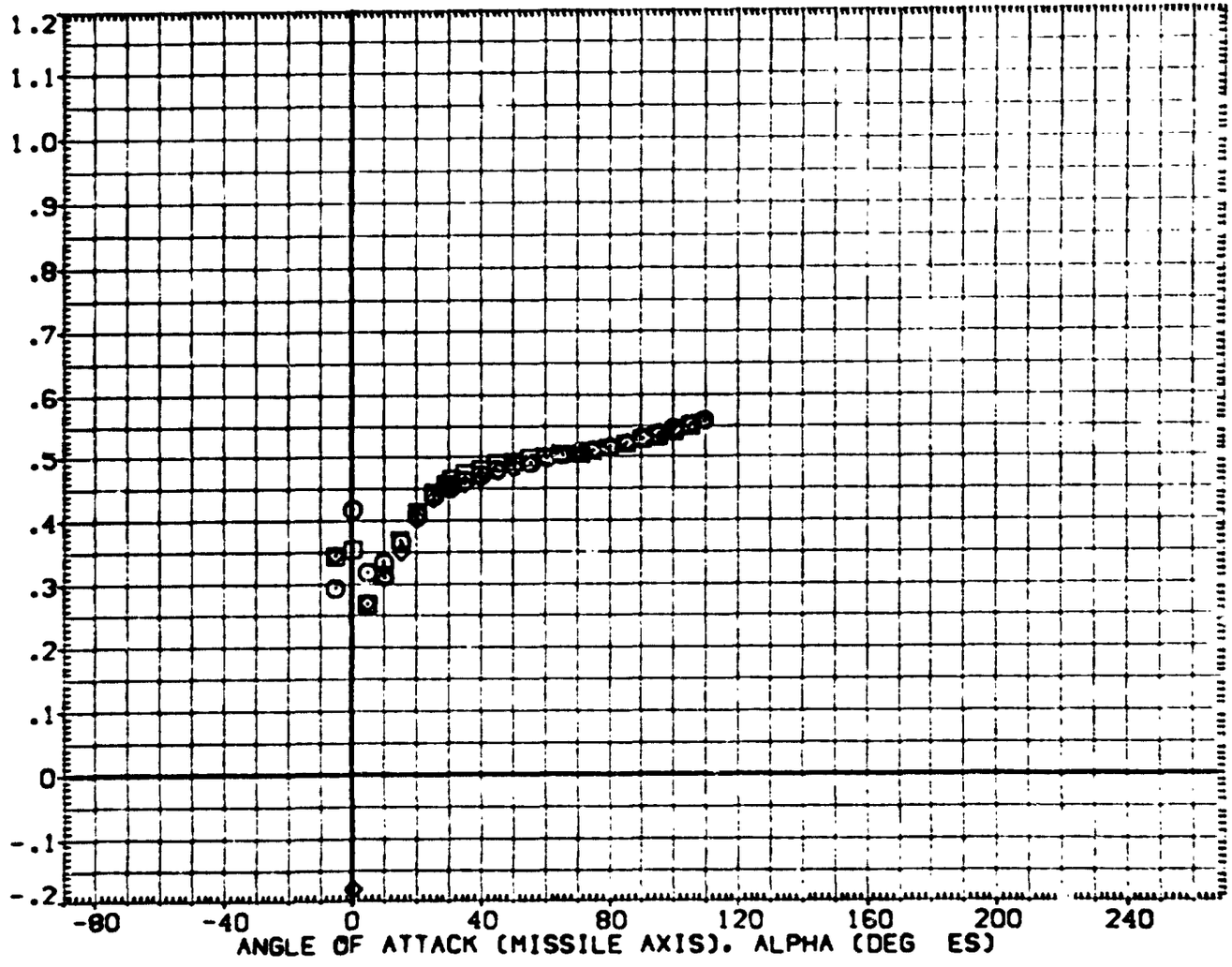

FIG. 11 C ARI OF YNOL BE

(A)PHI = .00

DATA SET		I TION IPTION	RN/L	
(VEYMA1)	□	ARC 3.5-196 TASF ET (TANK WITH)	10.400	1.160
(BEYMA4)	◇	ARC 3.5-196 TASF ET (TANK WITH PROTUBE S)	10.400	.390
( )	◇	ARC 3.5-196 TASF ET (TANK WITH PROTUBERANCES)	10.400	1.740

REFE	INF	TION -
SREF	594.1360	SQ.FT.
LREF	330.	IN.
BREF	330.	IN.
XMRP	1406.	IN.XT
YMRP	.	IN.YT
ZMRP	.	IN.ZT
SCALE	.	

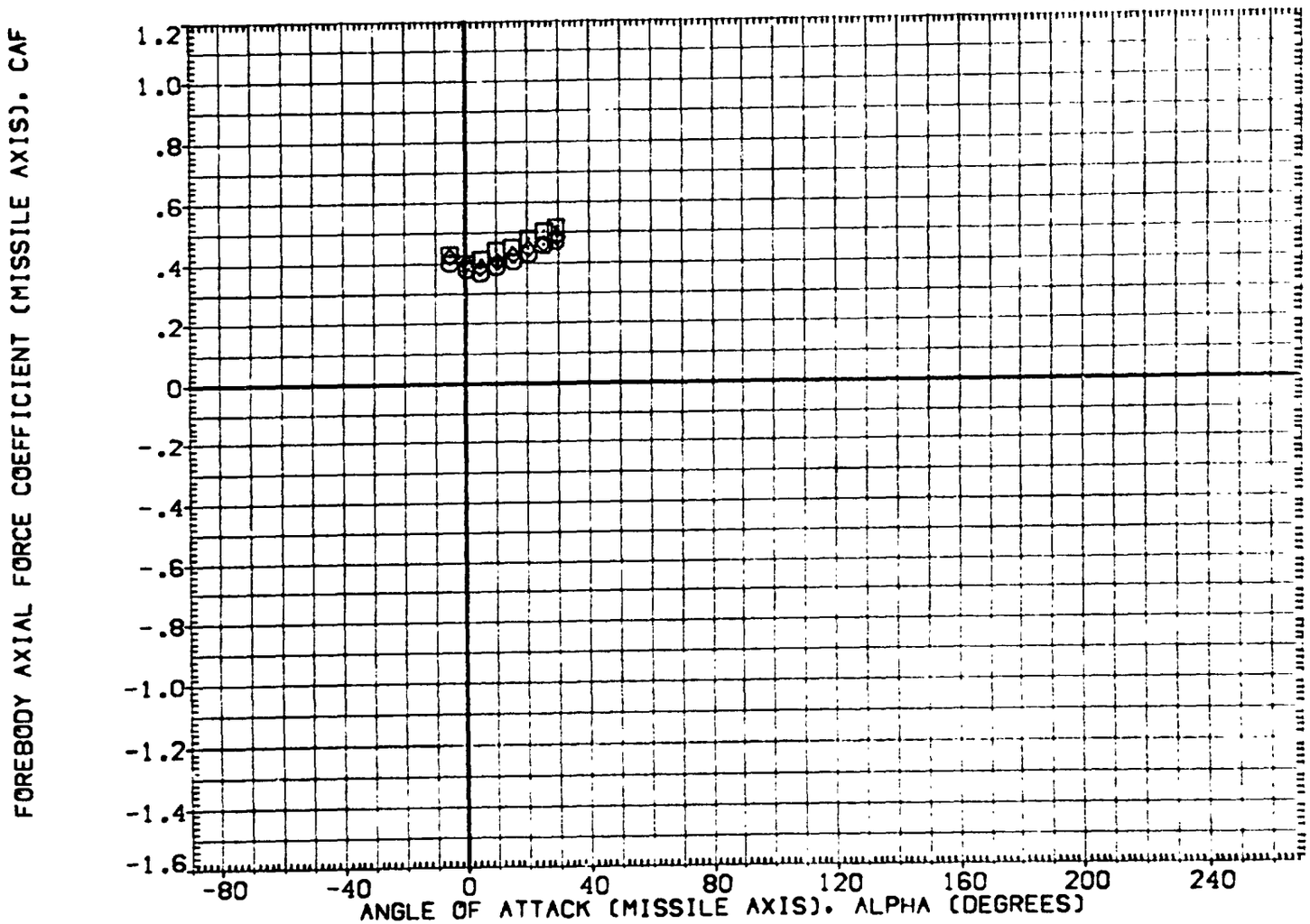

FIG. 11 COMPARISON OF REYNOLDS NUMBERS

(A)PHI = .00

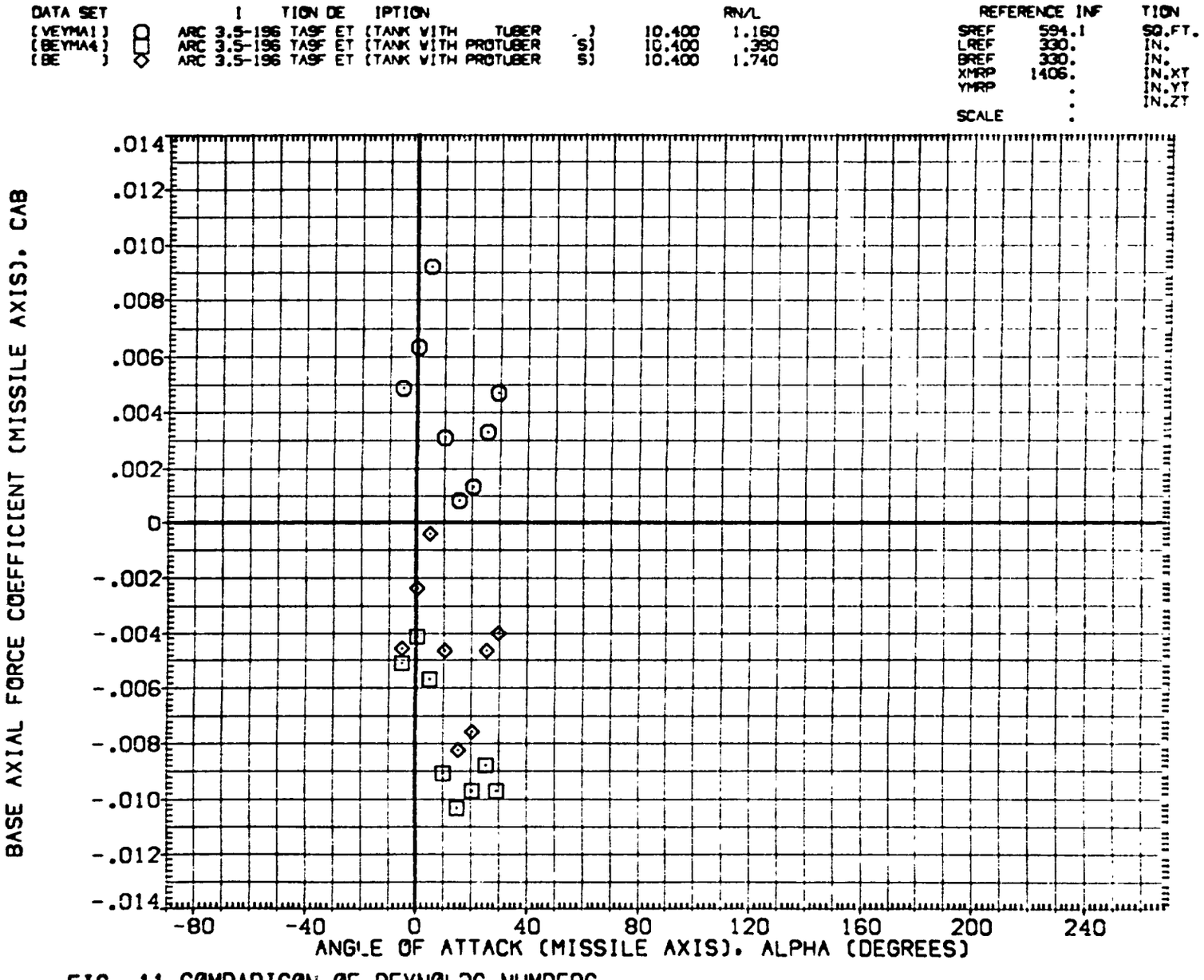

FIG. 11 COMPARISON OF REYNOLDS NUMBERS

(A)PHI = .00

DATA SET		DESCRIPTION	MACH	RN/L
(CEYMA1)	○	ARC 3.5-196 TASF ET (TANK WITH PROTUBER S)	10.400	1.160
(CEYMG1)	□	ARC 3.5-196 TASF ET (TANK WITH PROTUBERANCES)	10.400	1.160
(REYMA6)	⊠	ARC 3.5-196 TASF ET (TANK WITH PROTUBER S)	10.400	.390
(REYMG6)	△	ARC 3.5-196 TASF ET (TANK WITH PROTUBER S)	10.400	.

REFERENCE INFORMATION

SREF	594.1360	SQ.FT.
LREF	330.	IN.
BREF	330.	IN.
	1406.	IN.XT
	.	IN.YT
	.	IN.ZT
SCALE	.	

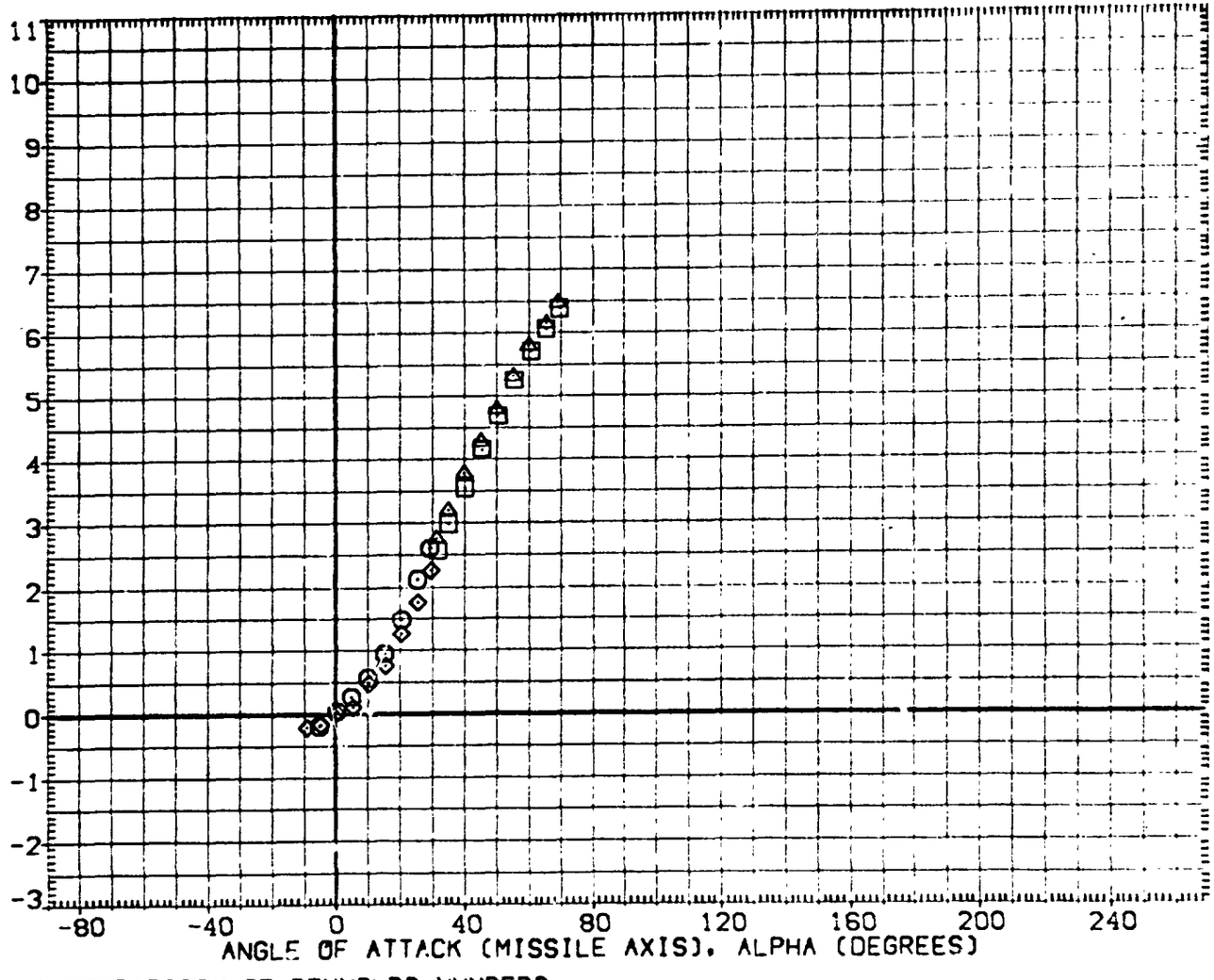

FIG. 11 COMPARISON OF REYNOLDS NUMBERS

(A)PHI =180.00

DATA SET S		I TION DE IPTION	MACH	RN/L
(CEYMA1)	□	ARC 3.5-196 TASF ET (TANK WITH UBE S)	10.400	1.160
(CEYMG1)	□	ARC 3.5-196 TASF ET (TANK WITH PROTUBERANCES)	10.400	1.160
(RE)	⊠	ARC 3.5-196 TASF ET (TANK WITH PROTUBERANCES)	10.400	.390
(RE)	△	ARC 3.5-196 TASF ET (TANK WITH PROTUBERANCES)	10.400	.390

REFERENCE INF		TION
SREF	594.1360	SQ.FT.
LREF	330.	IN.
BREF	330.	IN.
XMRP	1406.	IN.XT
YMRP	.	IN.YT
ZMRP	.	IN.ZT
SCALE	.	

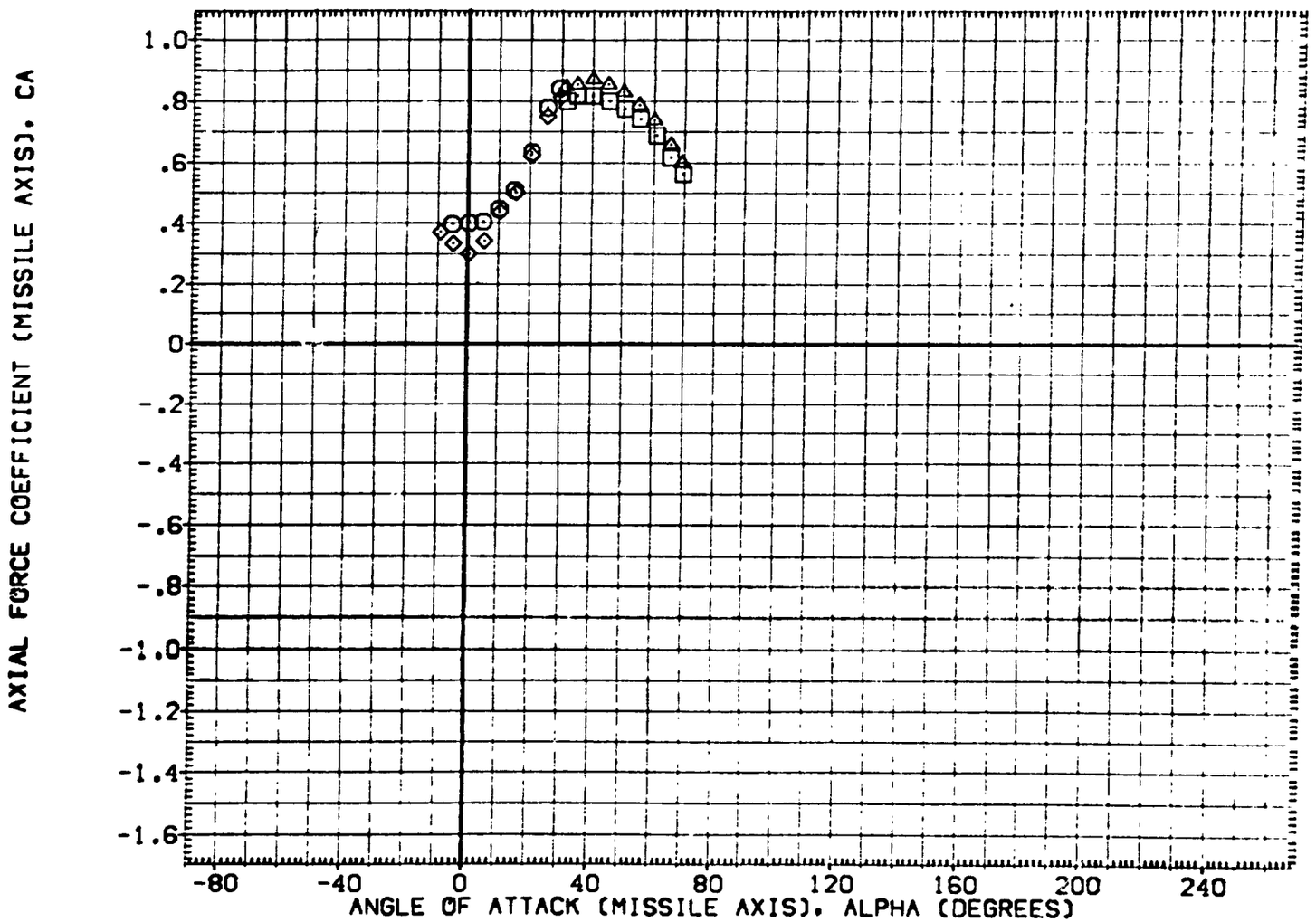

FIG. 11 COMPARISON OF REYNOLDS NUMBERS

(A)PHI =180.00

DATA SET		I TION DE IPTION	MACH	RN/L
(CEYMA1)	○	ARC 3.5-196 TASF ET (TANK WITH S)	10.400	1.160
(CEYMG1)	□	ARC 3.5-196 TASF ET (TANK WITH PROTUBERANCES)	10.400	1.160
(RE)	⊗	ARC 3.5-196 TASF ET (TANK WITH PROTUBERANCES)	10.400	.390
(RE)	△	ARC 3.5-196 TASF ET (TANK WITH PROTUBERANCES)	10.400	.390

REFERENCE I		TION
SREF	594.1360	SQ.FT.
LREF	330.	IN.
BREF	330.	IN.
	1406.	IN.XT
YMRP	.	IN.YT
ZMRP	.	IN.ZT
SCALE	.	

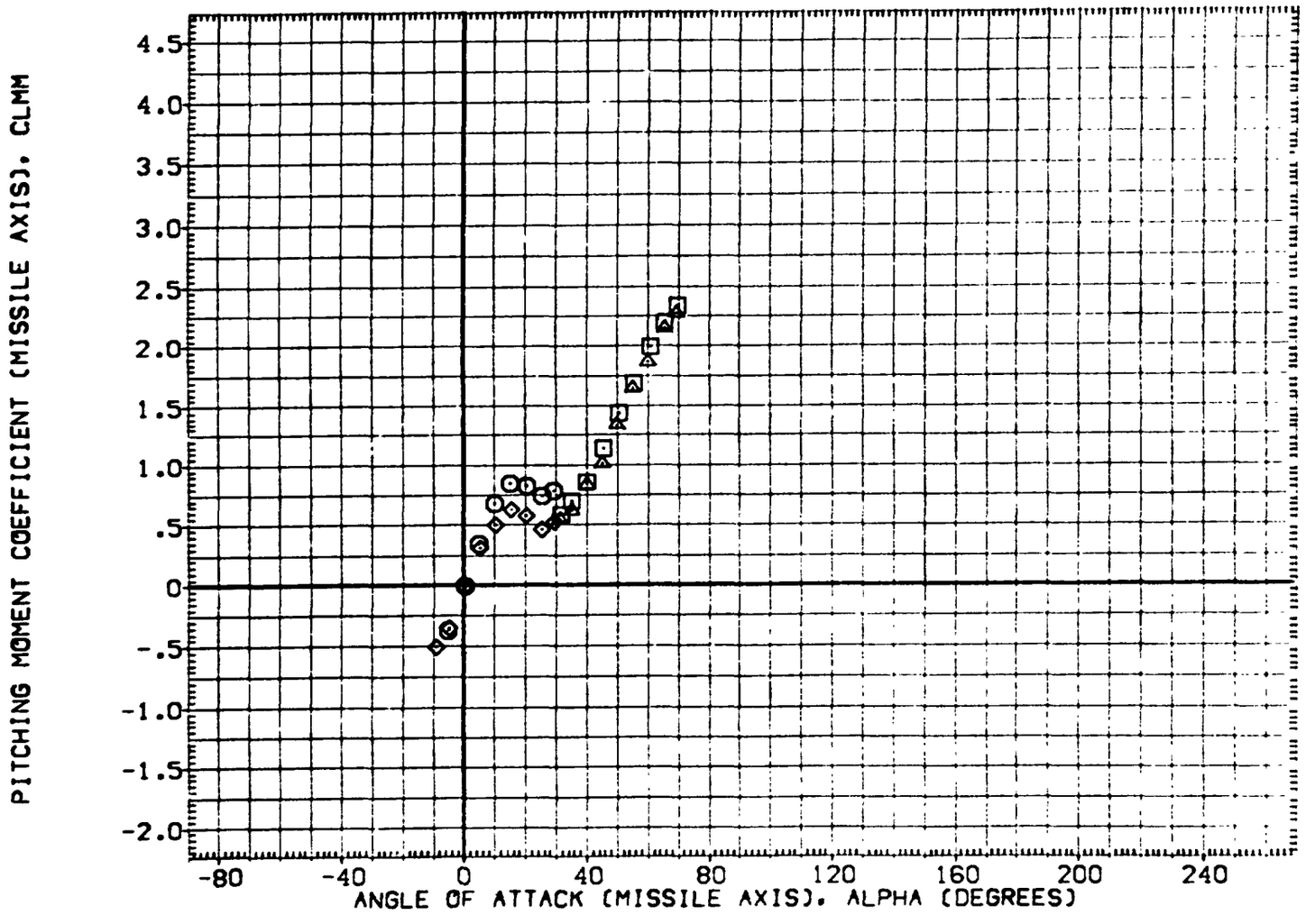

FIG. 11 COMPARISON OF REYNOLDS NUMBERS

(A)PHI =180.00

DATA SET		TION DE IPTION	MACH	RN/L
(CEYMA1)	○	ARC 3.5-196 TA9F ET (TANK WITH PRO S)	10.400	1.160
(CEYMG1)	□	ARC 3.5-196 TA9F ET (TANK WITH PROTUBERANCES)	10.400	1.160
(RE)	◇	ARC 3.5-196 TA9F ET (TANK WITH PROTUBERANCES)	10.400	.390
(REYMG6)	△	ARC 3.5-196 TA9F ET (TANK WITH PROTUBERANCES)	10.400	.390

	NCE INF	TION
SREF	594.1360	SQ.FT.
LREF	330.	IN.
BREF	330.	IN.
XMRP	1406.	IN.XT
YMRP	.	IN.YT
ZMRP	.	IN.ZT
SCALE	.	

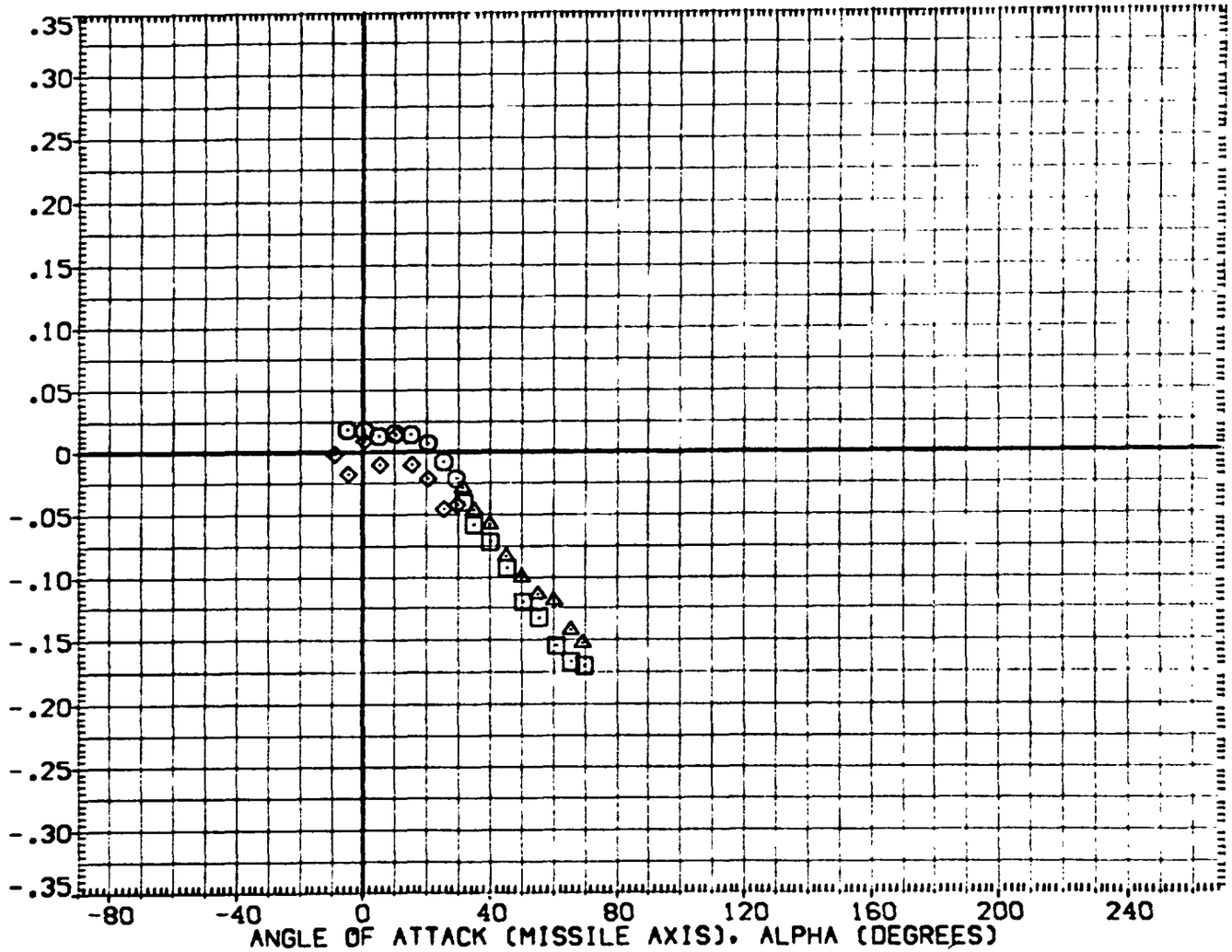

FIG. 11 COMPARISON OF REYNOLDS NUMBERS

(A)PHI =180.00

DATA SET		1 TION DESCRIPTION	MACH	RN/L
(CEYMA1)	○	ARC 3.5-196 TASF ET (TANK WITH)	10.400	1.160
(CEYMG1)	□	ARC 3.5-196 TASF ET (TANK WITH PROTUBERANCES)	10.400	1.160
(REYMAG)	◇	ARC 3.5-196 TASF ET (TANK WITH PROTUBE S)	10.400	.390
(RE)	△	ARC 3.5-196 TASF ET (TANK WITH PROTUBERANCES)	10.400	.390

REFERENCE INFORMATION

SREF	594.1360	SQ.FT.
LREF	330.	IN.
BREF	330.2000	IN.
XMRP	1406.	IN.XT
YMRP	.	IN.YT
SCALE	.	IN.ZT

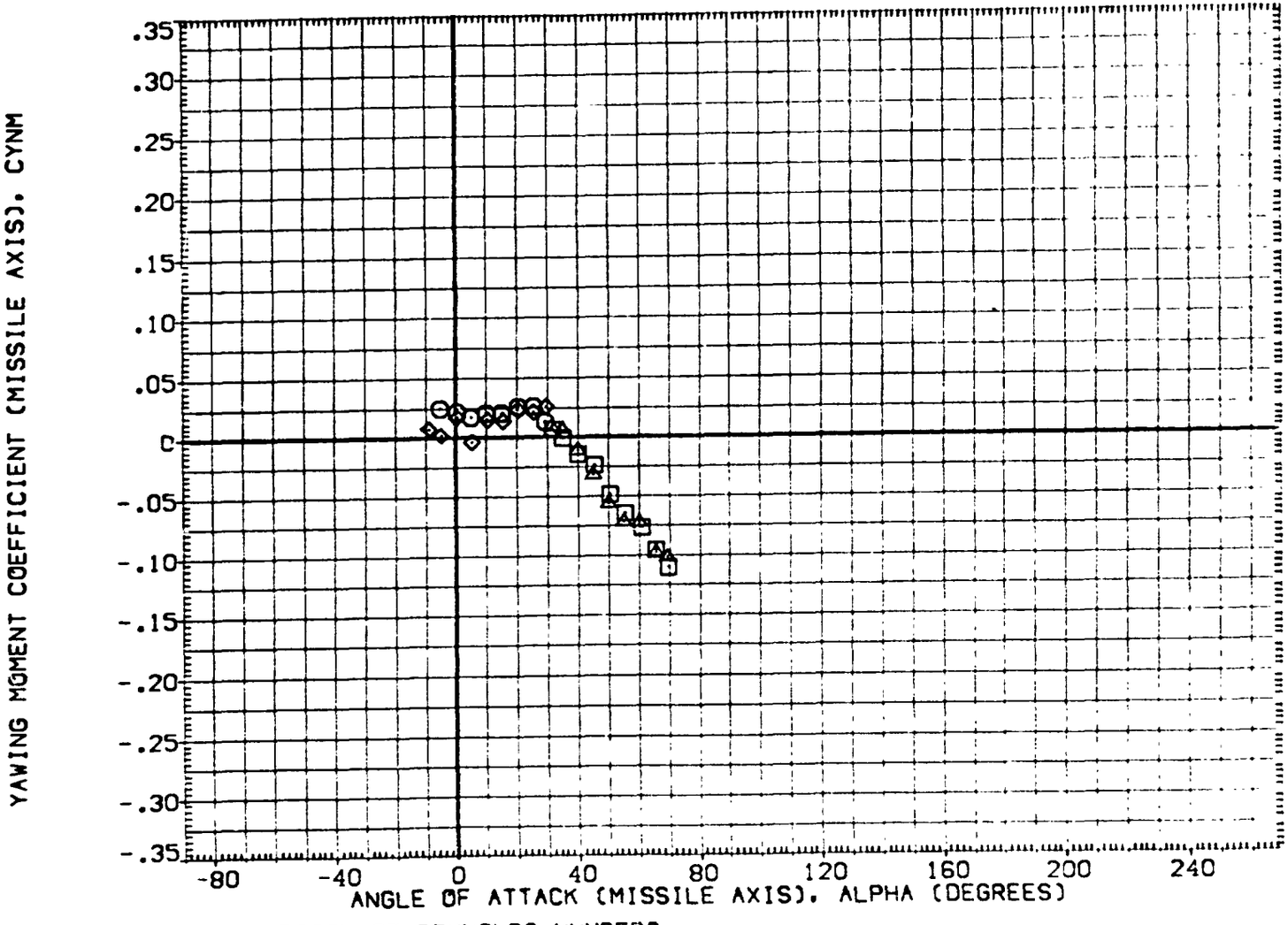

FIG. 11 COMPARISON OF REYNOLDS NUMBERS

(A)PHI =180.00

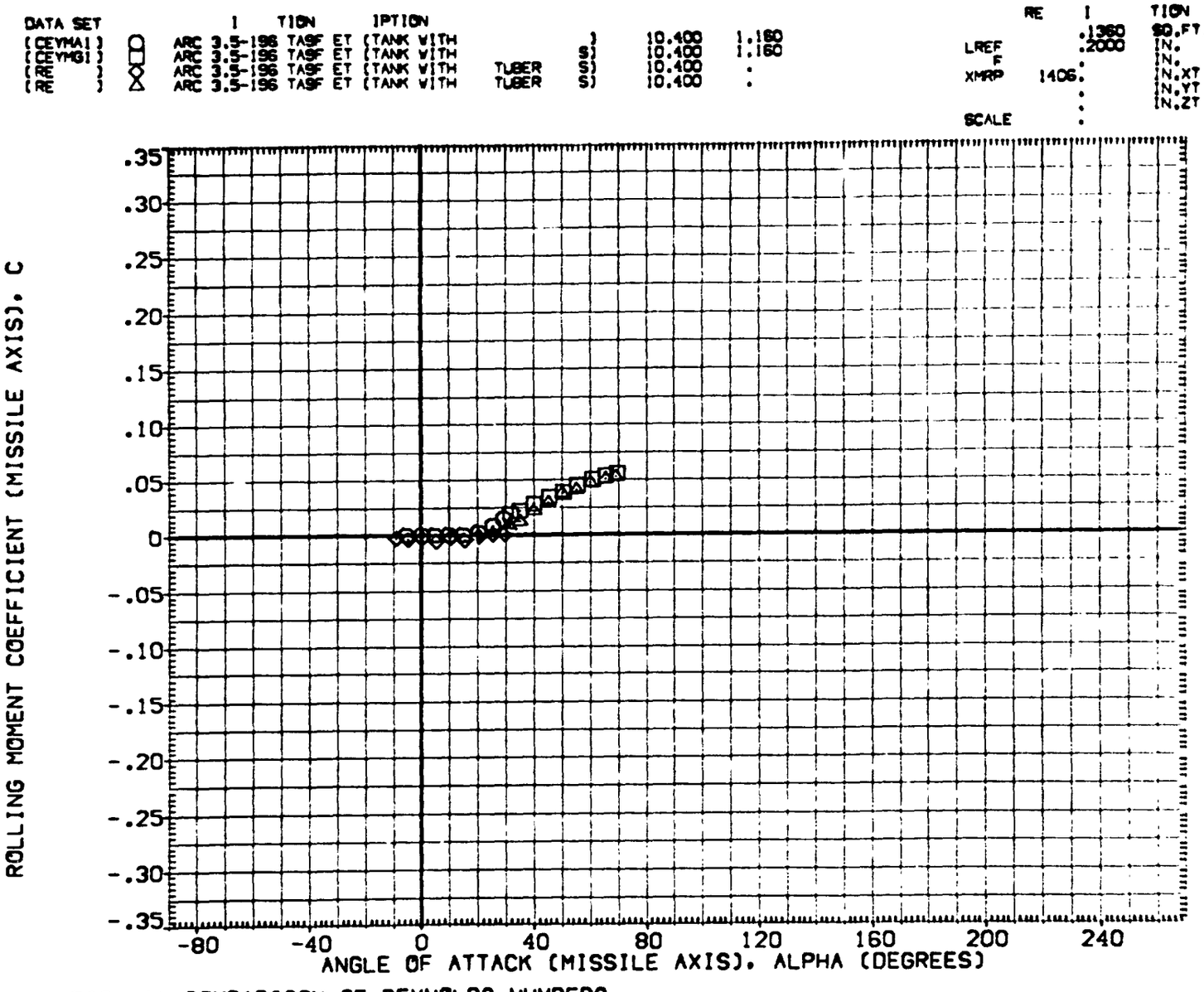

FIG. 11 COMPARISON OF REYNOLDS NUMBERS

(A)PHI =180.00

DATA SET	IGURATION DESCRIPTION	MACH	RN/L
(CEYMA1)	ARC 3.5-196 TASF ET (TANK WITH PROTUBERANCES)	10.400	1.160
(CEYMG1)	ARC 3.5-196 TASF ET (TANK WITH PROTUBERANCES)	10.400	1.160
(R E)	ARC 3.5-196 TASF ET (TANK WITH PROTUBERANCES)	10.400	.390
(R E)	ARC 3.5-196 TASF ET (TANK WITH PROTUBERANCES)	10.400	.390

REFERENCE INFORMATION

SREF	594.1360	SQ.FT.
LREF	330.2000	IN.
BREF	330.2000	IN.
XMRP	1406.0000	IN.XT
YMRP	.0000	IN.YT
ZMRP	.0000	IN.ZT
SCALE	.	

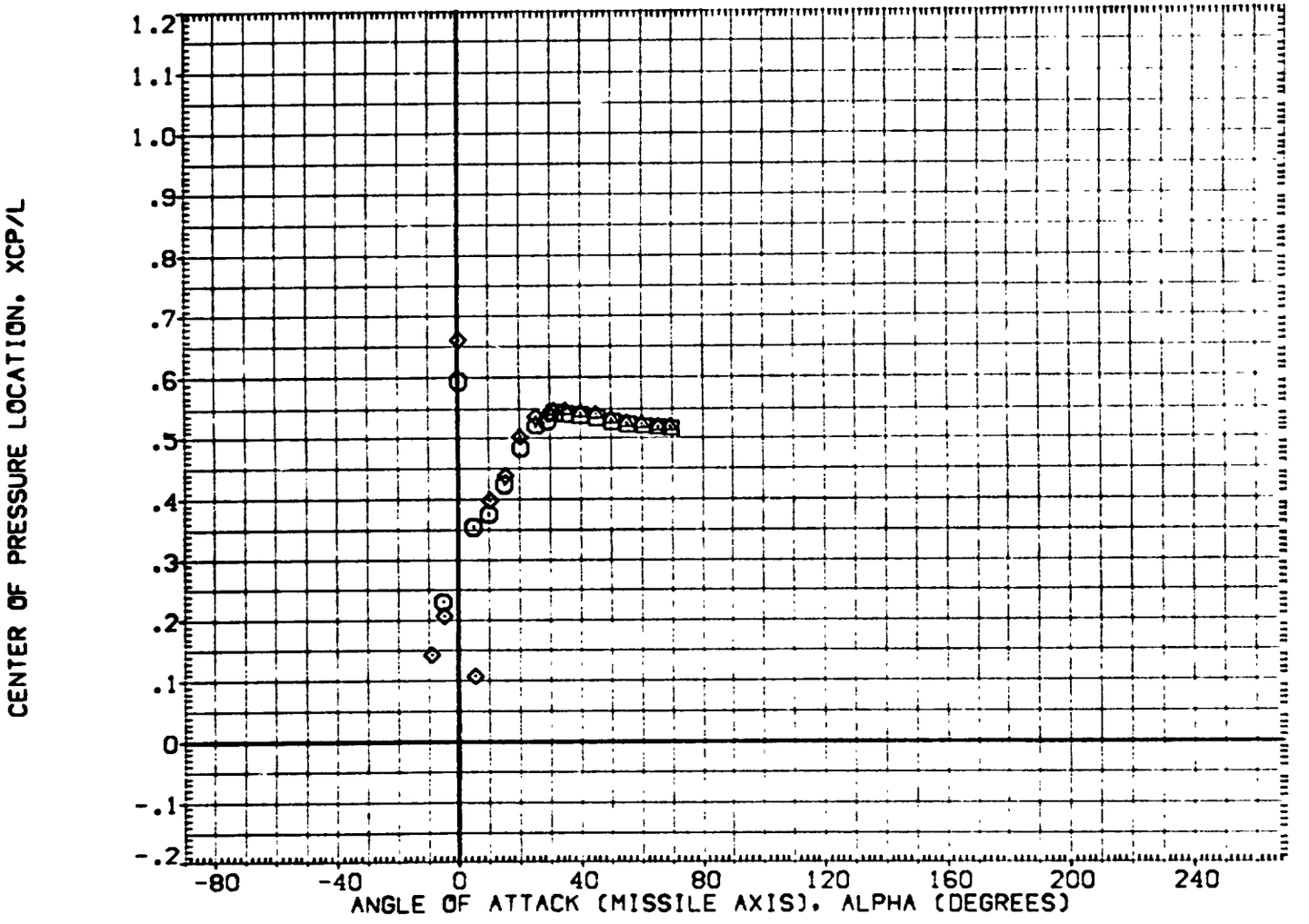

FIG. 11 COMPARISON OF REYNOLDS NUMBERS

(A)PHI =180.00

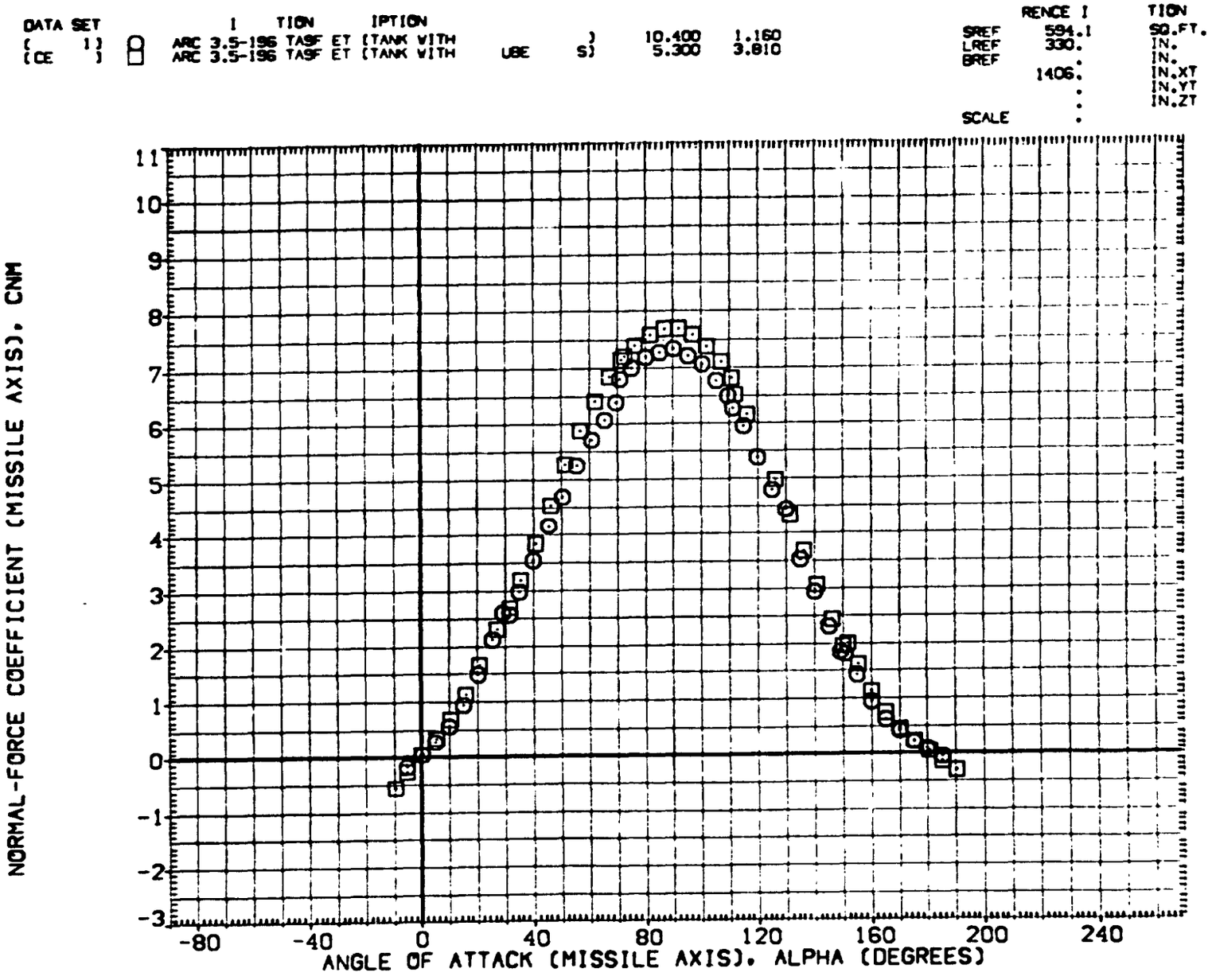

FIG. 12 MACH NUMBER AND REYNOLDS NUMBER COMPARISON

(A)PHI =180.00

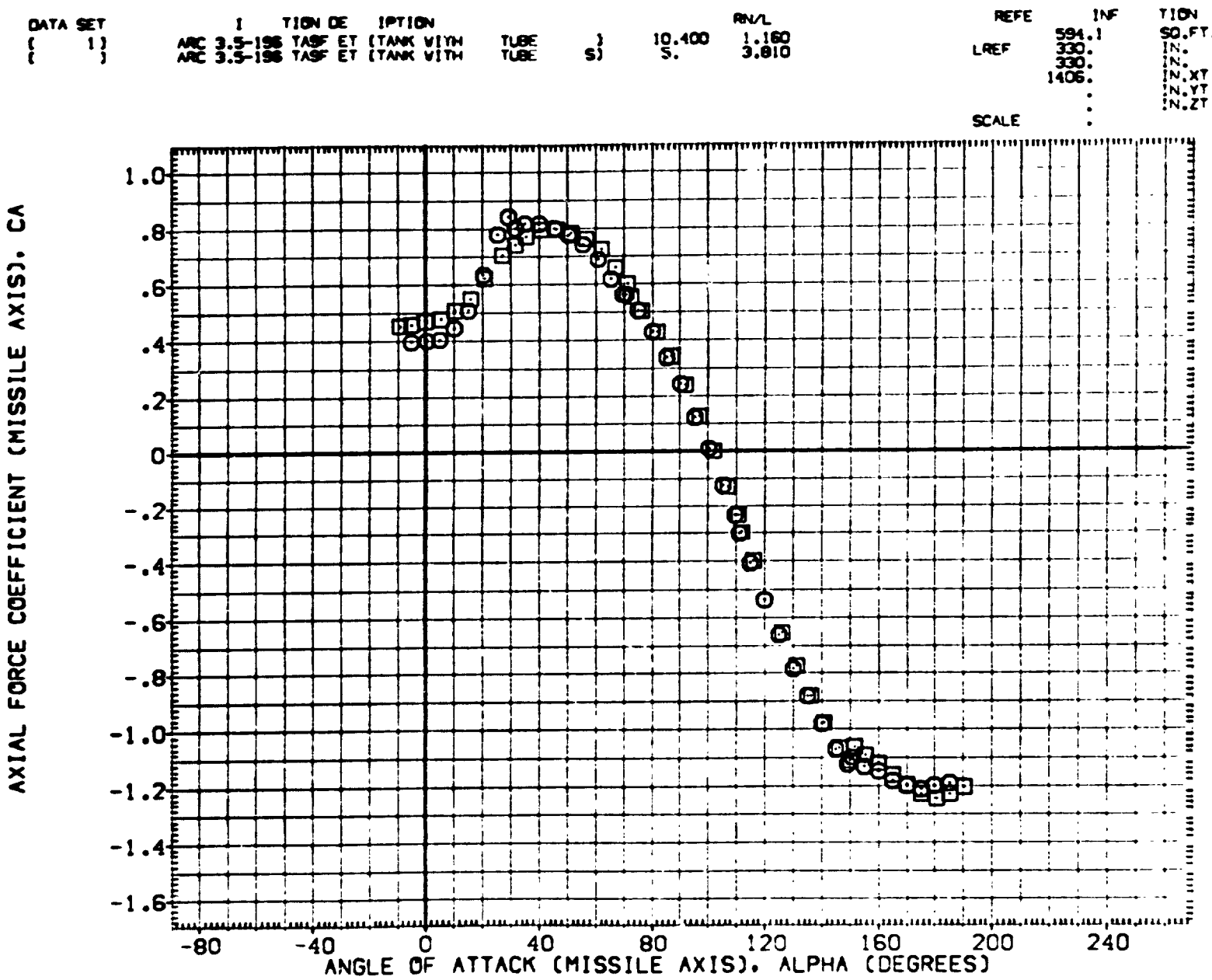

FIG. 12 MACH N BER AND REYNOLDS NUMBER COMPARISON

(A)PHI =180.00

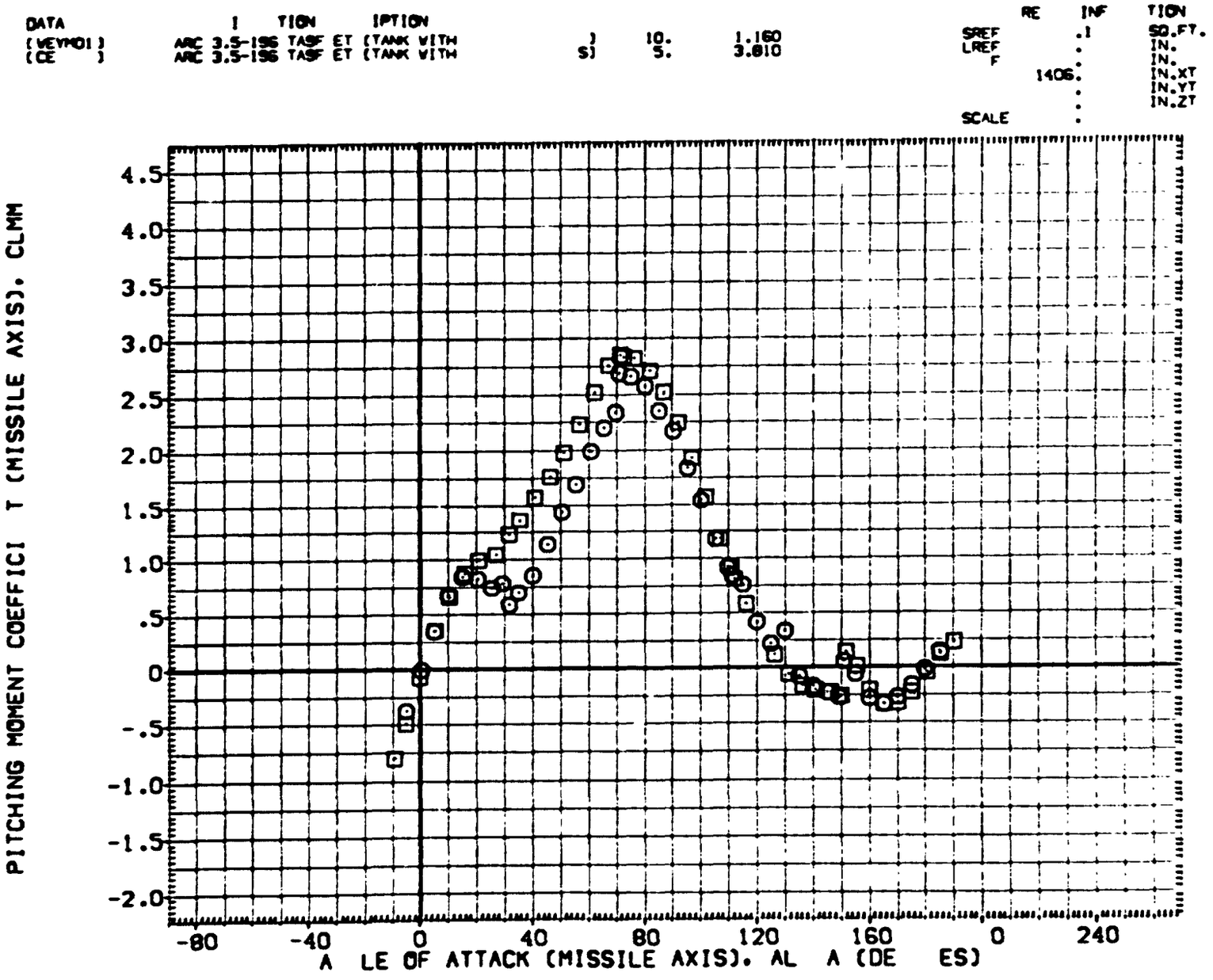

FIG. 12 MACH R AND REY LDS BER CO ARISON

(A)PHI =1 .00

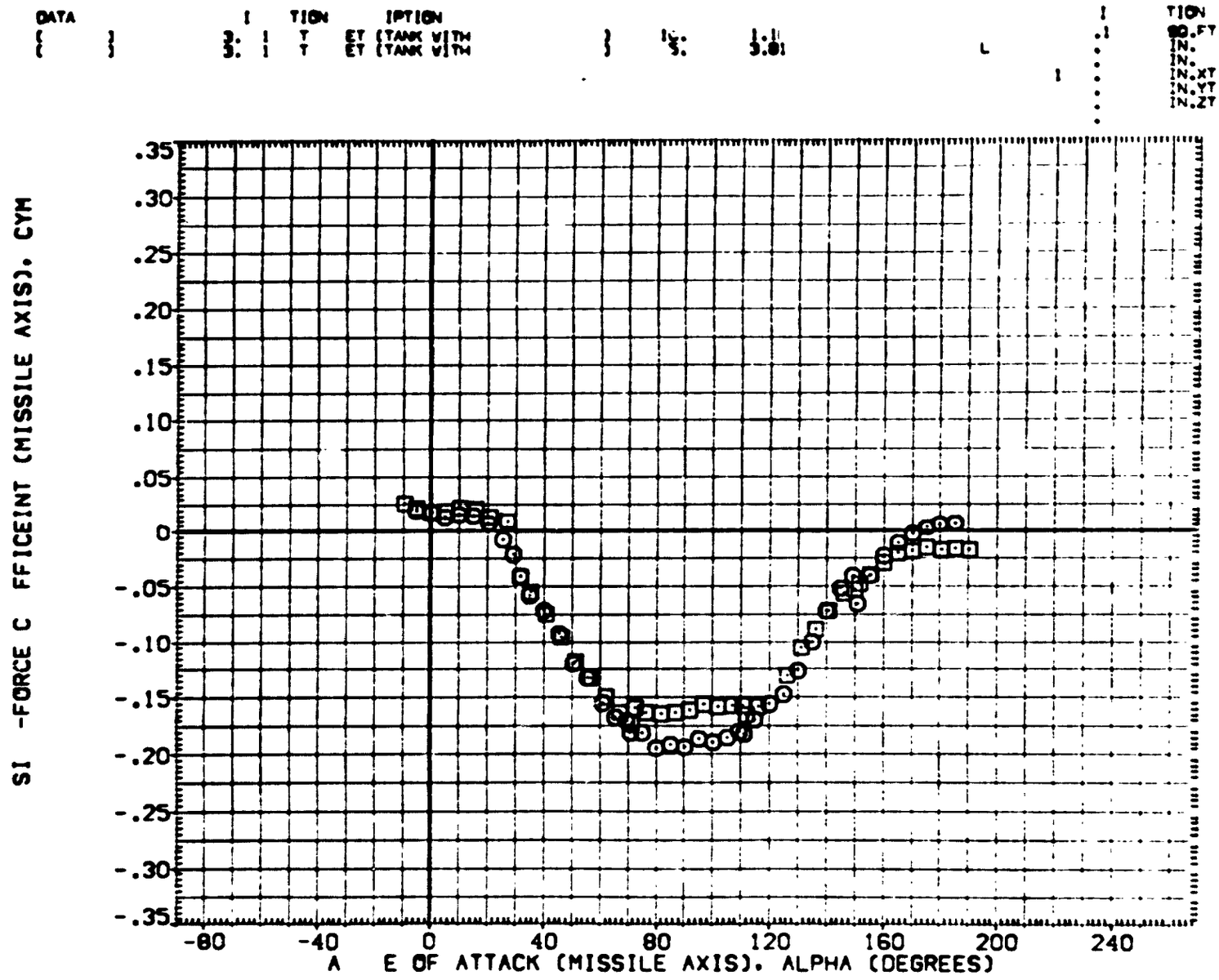

FIG. 12 MACH R A YNOLDS MBER COMPARISON

(A) I =180.00

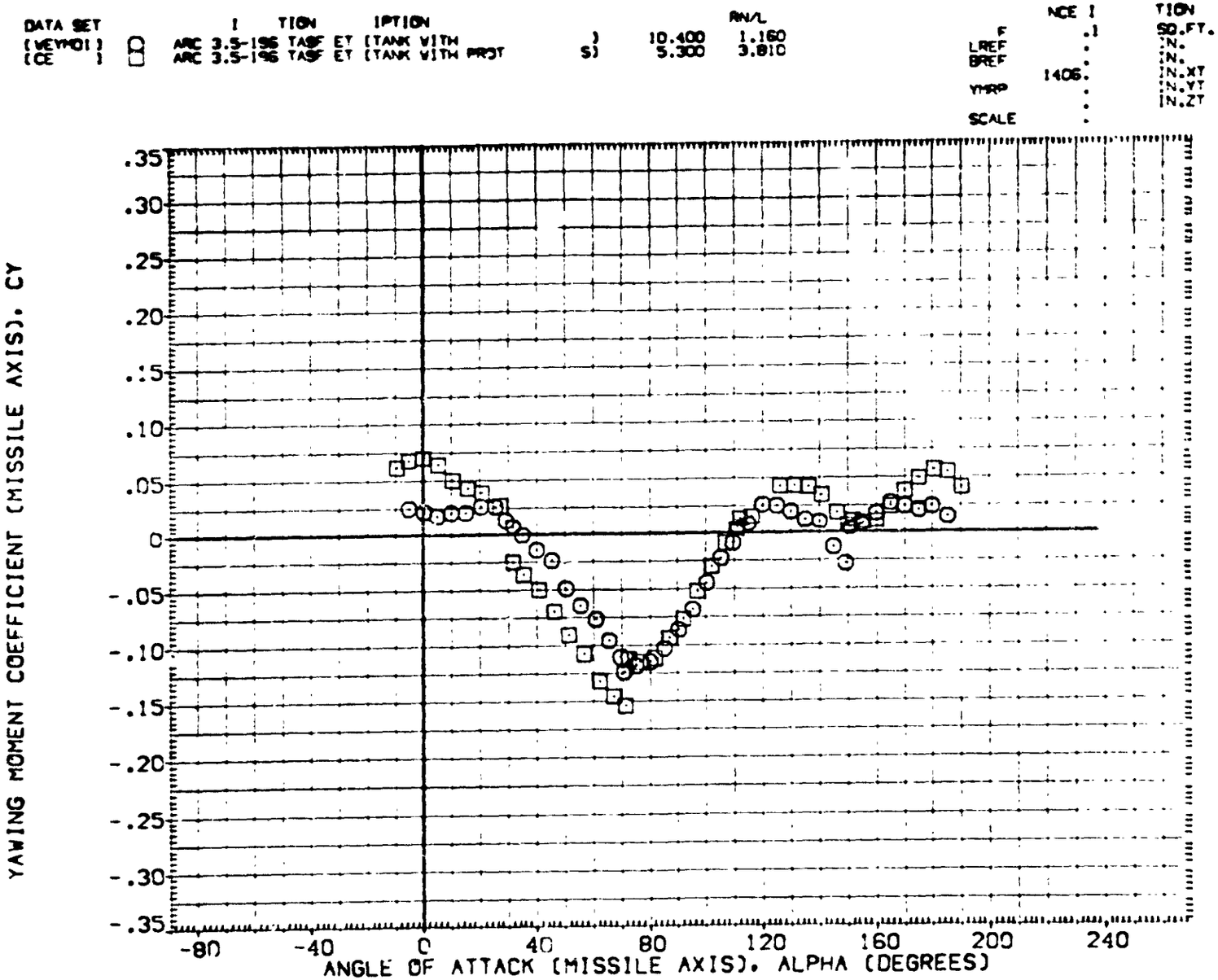

FIG. 12 MACH NUMBER AND REYNOLDS NUMBER COMPARISON

(A)PHI =180.00

DATA SET S		CONFIGURATION DESCRIPTION	MACH	RN/L
(WEYM01)	○	ARC 3.5-196 TA9F ET (TANK WITH PROTUBERANCES)	10.400	1.160
(CEYM03)	□	ARC 3.5-196 TA9F ET (TANK WITH PROTUBERANCES)	5.300	3.810

REFERENCE INFORMATION		
SREF	594.1360	SQ.FT.
LREF	330.2000	IN.
BREF	330.2000	IN.
XMRP	1406.0000	IN.XT
YMRP	.0000	IN.YT
ZMRP	.0000	IN.ZT
SCALE	.0060	

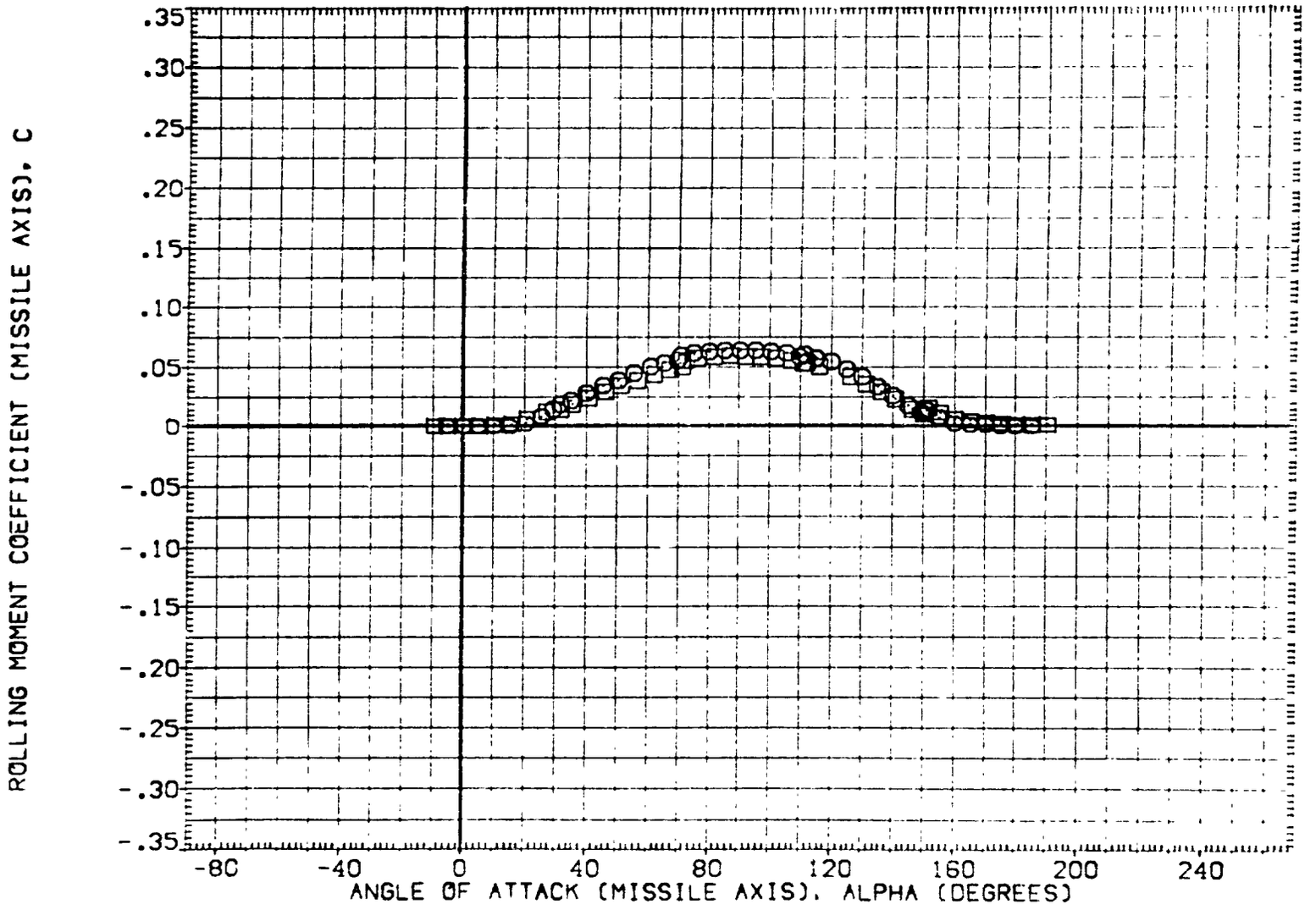

FIG. 12 MACH NUMBER AND REYNOLDS NUMBER COMPARISON

(A)PHI =180.00

DATA SET		IGURATION DESCRIPTION	MACH	RN/L
(VEYM01)	8	ARC 3.5-196 TASF ET (TANK WITH PRO R S)	10.400	1.160
(CE)	8	ARC 3.5-196 TASF ET (TANK WITH PROTUBERANCES)	5.300	3.810

REFERENCE INF		TION
SREF	594.1360	SQ.FT.
LREF	330.	IN.
BREF	330.	IN.
XMRP	1406.	IN.XT
YMRP	.	IN.YT
ZMRP	.	IN.ZT
SCALE	.	

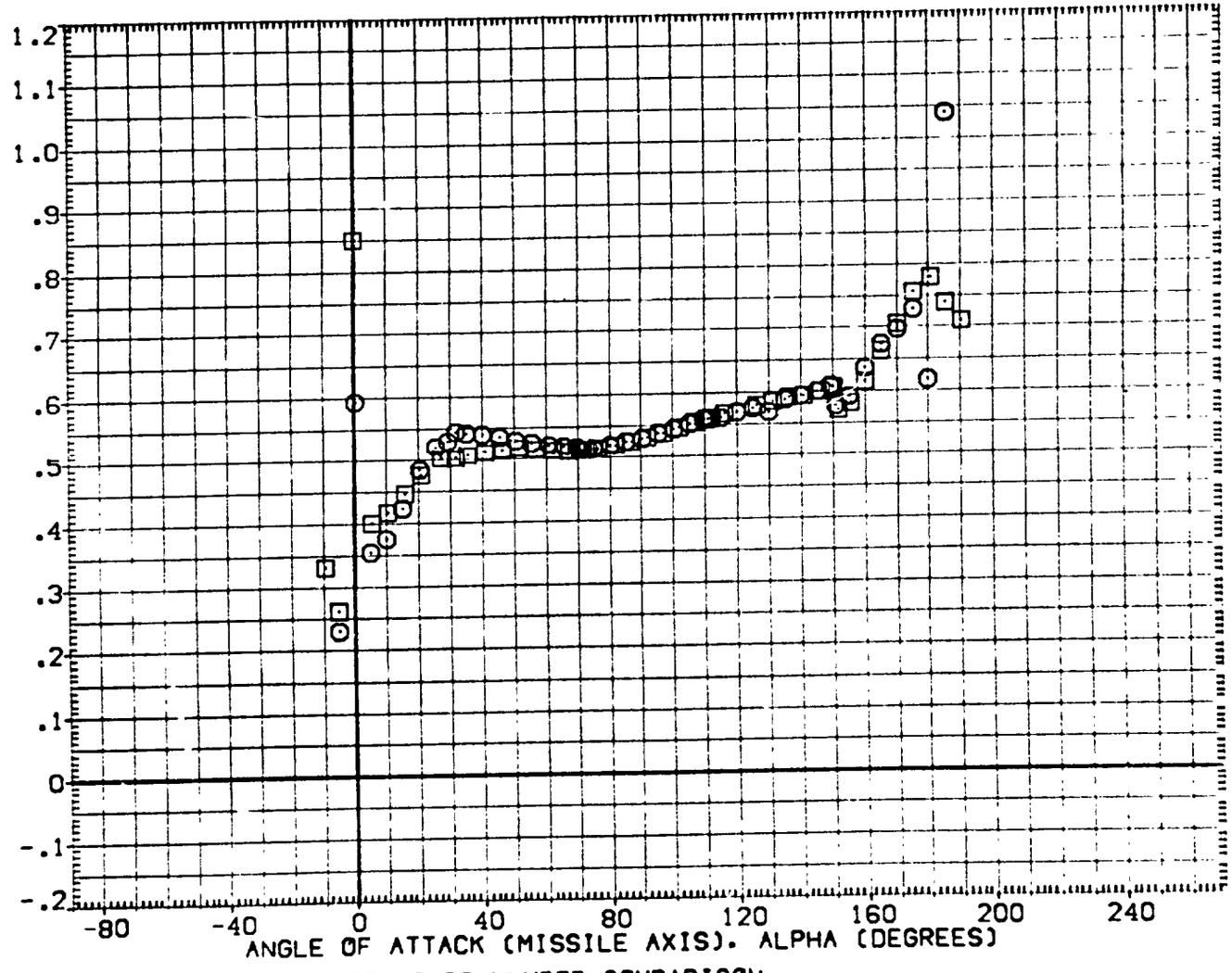

FIG. 12 MACH NUMBER AND REYNOLDS NUMBER COMPARISON

(A)PHI =180.00

APPENDIX

TABULATION SOURCE DATA

Plotted data tabulations are available from
Data Management Services on request.